

Micromite

User Manual

MMBasic Ver 5.04

For updates to this manual and more details on MMBasic go to

<http://geoffg.net/micromite.html>

and <http://mmbasic.com>

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Contributions

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Also thanks to the members of the [Back Shed forum](#) who have beta tested the Micromite firmware over the past few years and reported many, many bugs. Thanks guys.

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Introduction



The Micromite is a low cost Microchip PIC32 microcontroller programmed with the MMBasic firmware.

MMBasic is a Microsoft BASIC compatible implementation of the BASIC language with floating point, integer and string variables, arrays, long variable names, a built in program editor and many other features.

Using MMBasic you can use communications protocols such as I²C or SPI to get data from a variety of sensors. You can display data on low cost colour LCD displays, measure voltages, detect digital inputs and drive output pins to turn on lights, relays, etc. All from inside this cheap microcontroller.

Everything is internal to the Micromite and it will run from a couple of AA batteries. The only extra component required is a 47 μ F capacitor. The 28-pin dual in line version is particularly easy to use as it can be easily soldered or plugged into an IC socket. Even better, it costs just \$4.

In summary the features of the Micromite are:

- **A fast 32 bit CPU** with 256 KB of flash and 64 KB RAM running a powerful BASIC interpreter. 59 KB of non volatile flash memory is reserved for the program, 52 KB of RAM is available for BASIC variables, arrays, buffers, etc. This is sufficient for quite large BASIC programs up to 2500 lines or more.
- **The BASIC interpreter is full featured** with floating point, 64-bit integers and string variables, long variable names, arrays of floats, integers or strings with multiple dimensions, extensive string handling and user defined subroutines and functions. Typically it will execute a program at 30,000 lines per second. MMBasic allows the embedding of compiled C programs for high performance functions and the running program can be protected from being listed or modified by a PIN number.
- **Nineteen input/output pins** are available on the 28-pin chip and 33 on the 44-pin chip. These can be independently configured as digital input or output, analog input, frequency or period measurement and counting. Within MMBasic the I/O pins can be dynamically configured as inputs or outputs with or without pullups or pulldowns. MMBasic commands will generate pulses and can be used to transfer data in parallel. Interrupts can be used to notify when an input pin has changed state. Up to five PWM or SERVO outputs can be used to create various sounds, control servos or generate computer controlled voltages for driving equipment that uses an analogue input (eg, motor controllers).
- **TFT LCD display panels** using the ILI9341 and other controllers are supported allowing the BASIC program to display text and draw lines, circles, boxes, etc in 65,535 colours. Resistive touch controllers on these panels are also supported allowing them to be used as sophisticated input devices. These LCD panels typically cost US\$7 and provide a low cost, high tech graphical user interface.
- **Programming and control is done via a serial console** (TTL voltage levels) at 38400 baud (configurable). Once the program has been written and debugged the Micromite can be instructed to automatically run the program on power up with no user intervention. Special software is not needed to develop programs.
- **A full screen editor** is built into the Micromite. This only requires a VT100 terminal emulator and can edit the whole program in one session. It includes advanced features such as colour coded syntax, search and copy, cut and paste to and from a clipboard.
- **Programs can be easily transferred** from another computer (Windows, Mac or Linux) using the XModem protocol or by streaming the program over the serial console input.
- **A comprehensive range of communications protocols** are implemented including I²C, asynchronous serial, RS232, IEEE 485, SPI and 1-Wire. These can be used to communicate with many sensors (temperature, humidity, acceleration, etc) as well as for sending data to test equipment.
- **The Micromite has built in commands** to directly interface with infrared remote controls, the DS18B20 temperature sensor, LCD display modules, battery backed clock, numeric keypads and more.
- **Special embedded controller features** in MMBasic allow the CPU to be put to sleep or the clock speed to be varied to balance power consumption and speed. A watchdog feature will monitor the running program and can be used to restart the processor if the program fails with an error or is stuck in a loop.
- **Power requirements are 2.3 to 3.6 volts** at 6 to 31 mA.

Suitable Microcontrollers

The standard Micromite firmware will run on the following PIC32 microcontroller manufactured by Microchip. These are available from Microchip (<http://www.microchipdirect.com>) or their distributors – use Octopart (<http://octopart.com>) to search for suppliers.

See <http://microchip.com> for the data sheets.

28-pin Chips

The best chip to use is the PIC32MX170F256B-50I/SP which is guaranteed to run up to 48MHz (the maximum Micromite speed) and is in a 28-pin DIL package. It costs about \$4 direct from Microchip. There is a 40 MHz variant (the PIC32MX170F256B-I/SP) which is a little cheaper. All of the 40 MHz chips tested have run fine at 48MHz so this chip is also a good option.

The following is a summary of the recommended chips for the Micromite in a 28-pin package:

PIC32MX170F256B-50I/SP	Guaranteed to run at 48 MHz. 28-pin DIL package.
PIC32MX170F256B-50I/SO	As above but is in a surface mount SOIC package
PIC32MX170F256B-I/SP	Should run at 48 MHz despite its 40 MHz spec. 28-pin DIL package.
PIC32MX170F256B-I/SO	As above but is in a surface mount SOIC package

The firmware will also run on the PIC32MX270F256 series of chips. These have built in USB (which is not supported in the Micromite) and therefore you lose access to two I/O pins (pins 15 and 23) which are used in the chip for dedicated USB functions. In addition pins 21 and 22 are not 5V tolerant.

44-pin Chips

The best chip to use is the PIC32MX170F256D-50I/PT which is guaranteed to run up to 48 MHz and costs a little over \$4 when purchased from Microchip. Similar to the 28-pin package there are versions rated at 40 MHz and versions with USB - with the latter MMBasic does not support USB and you lose access to two I/O pins which are reserved for USB functions (pins 10 and 42).

The following is a summary of the recommended chips for the Micromite in a 44-pin package:

PIC32MX170F256D-50I/PT	Guaranteed to run at 48 MHz.
PIC32MX170F256DI/PT	Should run at 48 MHz despite its 40 MHz rating.

These chips are in a TQFP surface mount package with a lead pitch of 0.8mm. This is reasonably easy to solder and the chip can be mounted on a carrier board (for example futuralec.com part code 44PINTQFP) which brings the pins out on an easy to use 0.1 inch grid. Another excellent choice is the 44-pin Micromite module from micromite.org which includes a USB to serial converter and pre programmed microcontroller.

The Micromite firmware file will work with either the 28 or 44-pin chips. The only difference is that the 44-pin chip has an extra fourteen I/O pins that are accessible from within MMBasic.

PICMX150 Series Chips

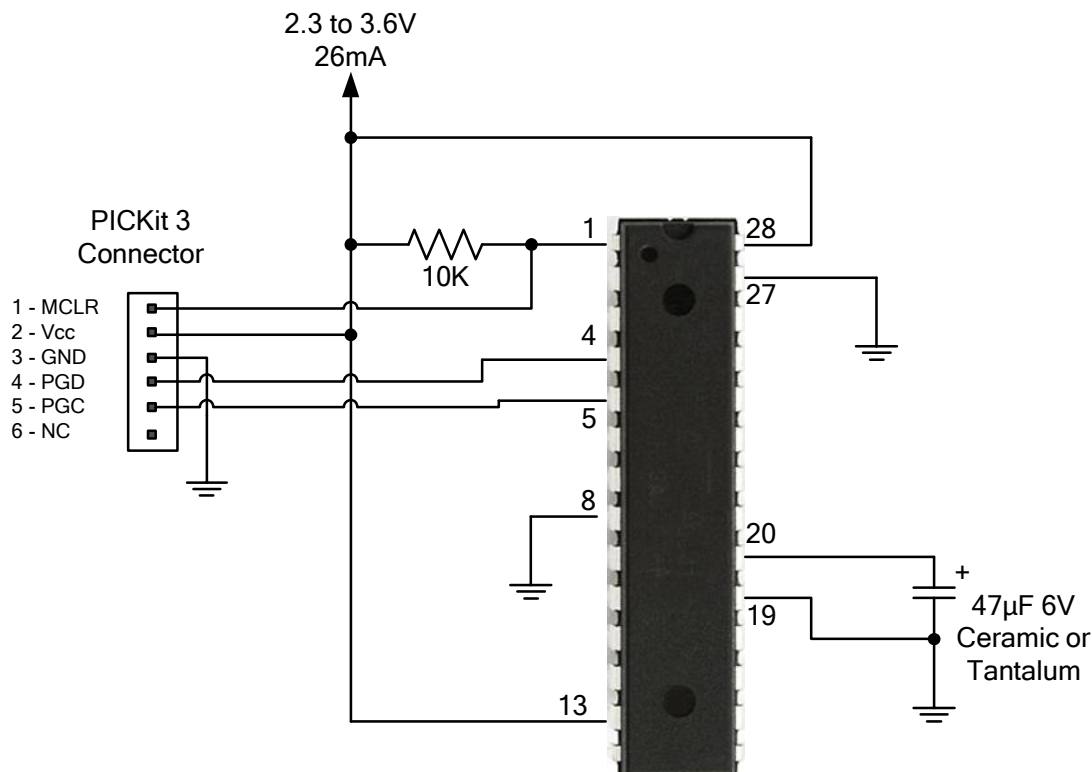
The first versions of the Micromite firmware ran on the PIC32MX150F128 series of chips. The firmware described in this manual will only run on the newer PIC32 chips listed above however the firmware for the original Micromite running on the MX150 series of chips is still available. It can be found in the download section of <http://geoffg.net/micromite.html> and is supplied with its own manual.

Programming the Firmware

28-pin Chips

To program the Micromite firmware into the microcontroller you need a suitable programmer. Probably the best is the Microchip PICKit 3 which is reasonably cheap at US\$45 and clones can be purchased on the Internet for less than \$20. If you install Microchip's MPLAB X (free from Microchip) it will also install MPLAB IPE which you can use with the PICKit 3 to program the chip. See geoffg.net/programming_pics.html for details.

These are the connections required for programming the 28-pin chip:



44-pin Chips

Programming these is similar to programming the 28-pin version. Refer to the following table for the pin connections on the microcontroller:

PICKit 3	Description	44-pin chip
	47µF Tantalum Capacitor to GND	7
1 - MCLR	Master Reset (active low)	18
2 - Vcc	Power Supply (3.3V)	17, 28 and 40
3 - GND	Ground	6, 16, 29 and 39
4 - PGD	Programming Data	21
5 - PGC	Programming Clock	22
6 - NC	Not used	

Notes:

- A pullup resistor of 10 K is required between the MCLR pin and Vcc.
- The microcontroller being programmed can be powered by the PICKit 3 but it is recommended that a separate power supply be used. When the PICKit 3 supplies the power pin 2 (Vcc) on the PICKit 3 will become an output supplying the power to the chip being programmed.

28-pin Micromite Connections

The following diagram shows the possible functions of each I/O pin on the Micromite.

Note that the physical pins on the chip and the pin numbers used in MMBasic are the same. This means that nine pins are not available in MMBasic as they are dedicated to functions such as power and ground. These pins are shaded in grey in the diagram.

<i>RESET</i> Wired to +V directly or via a 10K resistor	1	28	<i>ANALOG POWER (+2.3 to +3.6V)</i>
DIGITAL ANALOG	2	27	<i>ANALOG GROUND</i>
SPI OUT DIGITAL ANALOG	3	26	ANALOG DIGITAL PWM 2A
PWM 1A DIGITAL ANALOG	4	25	ANALOG DIGITAL SPI CLOCK
PWM 1B DIGITAL ANALOG	5	24	ANALOG DIGITAL PWM 2B
PWM 1C DIGITAL ANALOG	6	23	ANALOG DIGITAL
COM1: ENABLE DIGITAL ANALOG	7	22	DIGITAL 5V COM1: RECEIVE
<i>GROUND</i>	8	21	DIGITAL 5V COM1: TRANSMIT
COM2: TRANSMIT DIGITAL	9	20	<i>47µF TANT CAPACITOR (+)</i>
COM2: RECEIVE DIGITAL	10	19	<i>GROUND</i>
<i>CONSOLE Tx (DATA OUT)</i>	11	18	DIGITAL 5V COUNT I ² C DATA
<i>CONSOLE Rx (DATA IN)</i>	12	17	DIGITAL 5V COUNT I ² C CLOCK
<i>POWER (+2.3 to +3.6V)</i>	13	16	DIGITAL 5V COUNT WAKEUP IR
SPI IN 5V DIGITAL	14	15	DIGITAL 5V COUNT

The notation is as follows (the mnemonic in brackets is the mode used in the SETPIN command):

- ANALOG These pins can be used to measure voltage (AIN).
- DIGITAL Can be used for digital I/O including digital input (DIN) and digital output (DOUT).
- COUNT Can be used to measure frequency (FIN), period (PIN) or counting (CIN).
- 5V These pins can be connected to 5V circuits. All other I/O pins are strictly 3.3V maximum.
- COM *xxx* Can be used for serial communications (see Appendix A).
- I²C *xxx* Can be used for I²C communications (see Appendix B).
- SPI *xxx* Can be used for SPI I/O (see Appendix D).
- PWM *xxx* Can be used for PWM or SERVO output (see the PWM and SERVO commands).
- IR This can be used to receive signals from an infrared remote control (see the IR command).
- WAKEUP This pin can be used to wake the CPU from a sleep (see the CPU SLEEP command).

Pins 27 and 28 are the ground and power for analog measurements. Normally they are connected to the general ground and power (pins 8 and 13) but if you require noise free and accurate analog readings you should make sure that the power on pin 28 is regulated to precisely 3.3V and well filtered. Also your analog inputs should be referenced to pin 27 (the analog ground).

Within MMBasic the SETPIN command is used to set the function of an I/O pin for general I/O. The PIN command or function is then used to interact with the pin. For example, this will print out the voltage on pin 7:

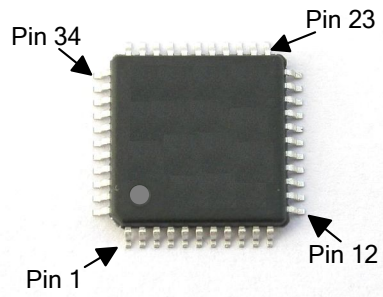
```
SETPIN 7, AIN
PRINT "The voltage is" PIN(7) "V"
```

This voltage reading is referenced to pin 28 and assumes that the supply voltage on this pin is exactly 3.3V. You will need to scale the readings in your BASIC program if you use a supply voltage other than this.

44-pin Micromite Connections

The following diagram shows the possible functions of each I/O pin on the 44-pin Micromite.

Note that the physical pins on the chip and the pin numbers used in MMBasic are the same. This means that eleven pins are not available in MMBasic (these pins are shaded in grey).



	Pin	Pin	
ANALOG DIGITAL PWM 1C	23	22	PWM 1B DIGITAL ANALOG
ANALOG DIGITAL COM1: ENABLE	24	21	PWM 1A DIGITAL ANALOG
ANALOG DIGITAL	25	20	SPI OUT (MOSI) DIGITAL ANALOG
ANALOG DIGITAL	26	19	DIGITAL ANALOG
ANALOG DIGITAL	27	18	<i>RESET Wired to +V directly or via 10K resist</i>
<i>POWER (+2.3 to +3.6V)</i>	28	17	<i>ANALOG POWER (+2.3 to +3.6V)</i>
<i>GROUND</i>	29	16	<i>ANALOG GROUND</i>
DIGITAL COM2: TRANSMIT	30	15	PWM 2A DIGITAL ANALOG
DIGITAL COM2: RECEIVE	31	14	SPI CLOCK DIGITAL ANALOG
DIGITAL 5V	32	13	5V DIGITAL
<i>CONSOLE Tx (DATA OUT)</i>	33	12	5V DIGITAL
<i>CONSOLE Rx (DATA IN)</i>	34	11	PWM 2B DIGITAL ANALOG
DIGITAL 5V	35	10	DIGITAL ANALOG
DIGITAL	36	9	COM1: RECEIVE 5V DIGITAL
DIGITAL 5V	37	8	COM1: TRANSMIT 5V DIGITAL
DIGITAL 5V	38	7	<i>47µF TANT CAPACITOR (+)</i>
<i>GROUND</i>	39	6	<i>GROUND</i>
<i>POWER (+2.3 to +3.6V)</i>	40	5	5V DIGITAL
DIGITAL 5V SPI IN (MISO)	41	4	5V DIGITAL
DIGITAL 5V COUNT	42	3	5V DIGITAL
DIGITAL 5V COUNT WAKEUP IR	43	2	5V DIGITAL
DIGITAL 5V COUNT I ² C CLOCK	44	1	I ² C DATA COUNT 5V DIGITAL

The notation is the same as described for the 28-pin version.

Console Connection

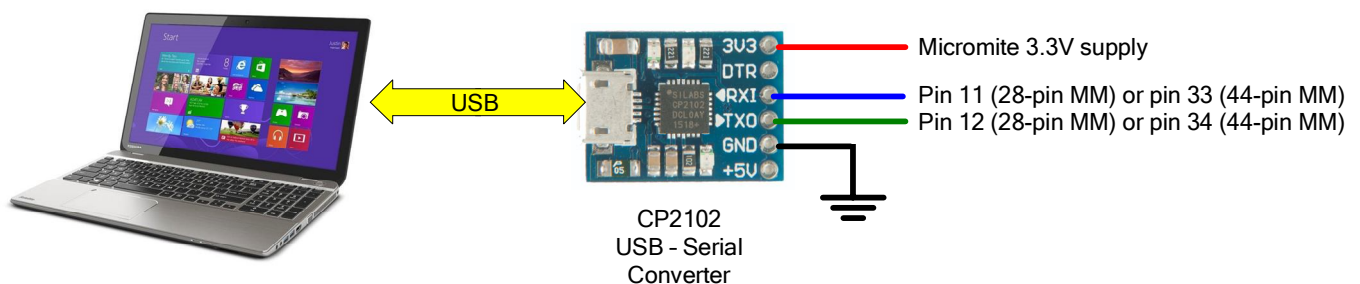
To write and debug your BASIC programs and configure the Micromite you use the console. This is a serial interface running at 38400 baud which uses TTL signal levels. This is similar to the RS232 interface on older personal computers but the TTL signal level is inverted and swings from zero to 3.3V.

There are many USB to serial converters on the market. These provide a TTL level serial interface on one side and a USB interface on the other. When connected to your computer the converter will appear as a virtual serial port. Recommended are converters based on the Silicon Labs CP2102 chip, they can be found on eBay for a few dollars (search for "CP2102") and work perfectly with the Micromite. You should avoid converters based on the FTDI FT232RL chip as many Chinese manufacturers use non genuine chips which will not work with the current Windows drivers.

The serial interface side of the converter will generally have a ground pin and a 3.3V power output pin and this can be used to power the Micromite. The converter will also have two pins marked TX (or similar) for transmit and RX (or similar) for receive. The TX pin of the serial converter must go to the RX pin of the Micromite and the RX pin must go to the TX pin.

If you have a serial converter that operates at 5V you can still use it with the Micromite. All you need do is place a 1K resistor in series with the transmit signal from the converter. The resistor will limit the current to a safe level.

Below is a typical connection using the CP2102 converter:



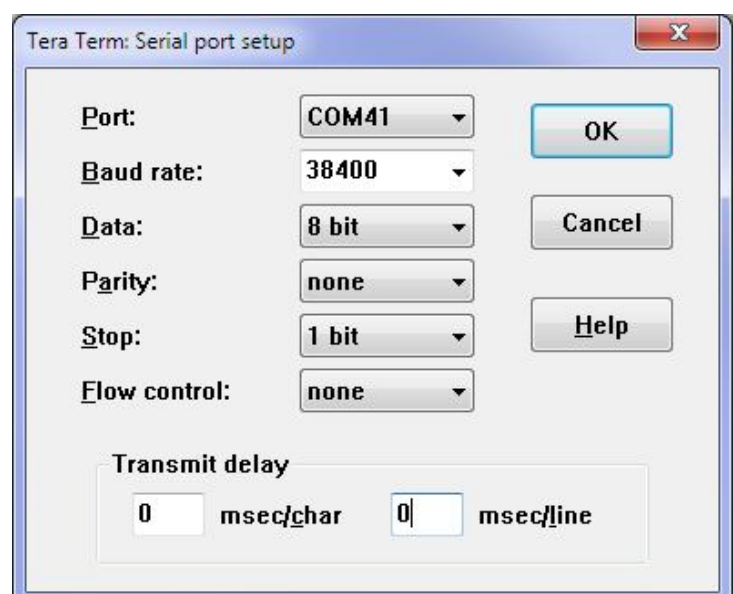
When you plug the USB side of the converter into your computer you may have to load a driver to make it work with the operating system. Once this is done you should note the port number created by your computer for the virtual serial connection. In Windows this can be done by starting Device Manager and checking the "Ports (COM & LPT)" entry for a new COM port.

Terminal Emulator

You also need a terminal emulator program on your desktop computer. This program acts like an old fashioned computer terminal where it will display text received from a remote computer and any key presses will be sent to the remote computer over the serial link.

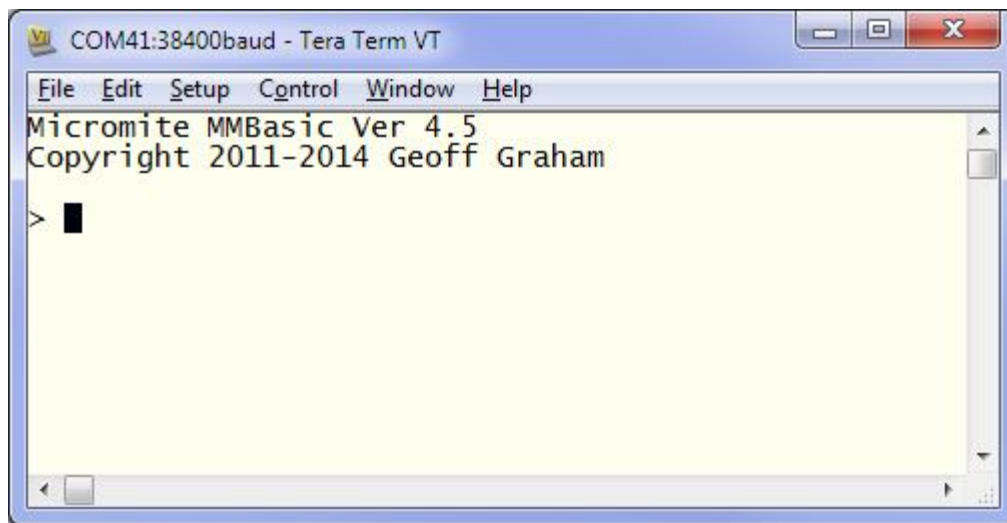
The terminal emulator that you use should support VT100 emulation as that is what the editor built into the Micromite expects. For Windows users it is recommended that you use Tera Term as this has a good VT100 emulator and is known to work with the XModem protocol which you can use to transfer programs to and from the Micromite (Tera Term can be downloaded from: <http://tera-term.en.lo4d.com/>).

The terminal emulator and the serial port that it is using should be set to the Micromite standard of 38400 baud, 8 data bits and one stop bit. The screen shot on the right shows the setup for Tera Term. Note that the "Port:" setting will vary depending on which USB port your USB to TTL serial converter was plugged into.



If you are using Tera Term do not set a delay between characters and if you are using Putty set the backspace key to generate the backspace character.

When you have the serial port and terminal emulator setup you can apply power to the Micromite and you should see the MMBasic banner and prompt on your screen similar to that shown below.



Troubleshooting

If you cannot see the startup banner try disconnecting the USB-serial converter and join its TX and RX pins. Then try typing something into the terminal emulator. You should see your characters echoed back, if not it indicates a fault with the converter or the terminal emulator.

If the USB-serial converter checks out the fault could be related to the console connection to the Micromite. Make sure that TX connects to RX and vice versa and that the baudrate is 38400. If you have an oscilloscope you should be able to see a burst of activity on the Micromite's TX line on power up. This is the Micromite sending its startup banner.

Shortcut Keys

When you are using a VT100 compatible terminal emulator on the console you can use the following function keys to insert a command at the command prompt:

F2	RUN
F3	LIST
F4	EDIT
F10	AUTOSAVE
F11	XMODEM RECEIVE
F12	XMODEM SEND

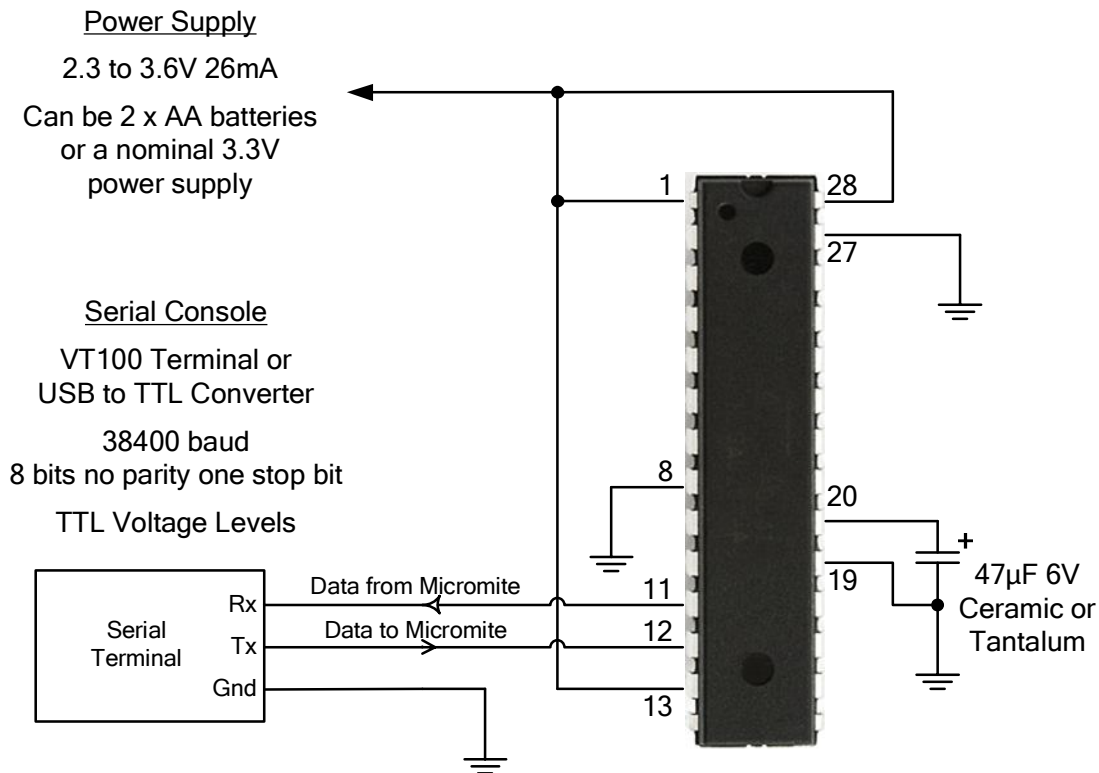
Pressing the key will insert the text at the command prompt, just as if it had been typed on the keyboard.

Quick Start Tutorial

The following assumes that you have programmed MMBasic into a suitable microcontroller and that you have the console connected to a suitable terminal emulator (see the previous chapter).

Basic Circuit

The basic circuit for the 28-pin Micromite is shown below. Because the Micromite only consists of the PIC32 chip and one capacitor it is recommended that you experiment with it using a plug in breadboard with jumper leads. Later, when you have finalised your design, you can create a printed circuit board to hold the final circuit.



Power Supply

The Micromite needs a power supply between 2.3V and 3.6V connected as shown above. Normally the current drain is 26mA plus the drain of any external components (LEDS, etc). Two alkaline AA cells can provide a convenient power source or you can use a conventional power supply.

Generally it is a good design technique to place a 100nF ceramic capacitor close to each of the power supply pins but this is not critical and they are not shown in this diagram.

The capacitor connected to pin 20 is used to decouple and stabilise the 1.8V voltage regulator internal to the PIC32 chip. It must be a high quality capacitor (not an electrolytic) and should have a minimum value of 10µF with an ESR (Equivalent Series Resistance) of less than 1Ω. The recommended capacitor is a 47µF tantalum or a 10µF multilayer ceramic.

A Simple Program

Assuming that you have correctly connected a terminal emulator to the Micromite and have the command prompt (the greater than symbol as shown above, ie, >) you can enter a command line followed by the enter key and it will be immediately run.

For example, if you enter the command PRINT 1/7 you should see this:

```
> PRINT 1/7
0.142857
>
```

This is called immediate mode and is useful for testing commands and their effects.

To enter a program you can use the `EDIT` command which is fully described later in this manual. However to get a quick feel for how it works, try this sequence (your terminal emulator must be VT100 compatible):

- At the command prompt type `EDIT` followed by the ENTER key.
- The editor should start up and you can enter this line: `PRINT "Hello World"`
- Press the F1 key in your terminal emulator (or CTRL-Q which will do the same thing). This tells the editor to save your program and exit to the command prompt.
- At the command prompt type `RUN` followed by the ENTER key.
- You should see the message: `Hello World`

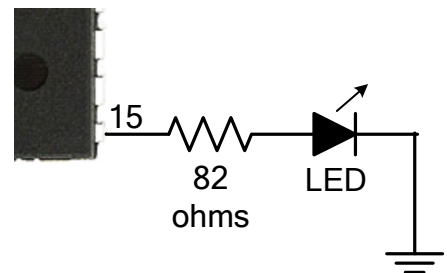
Congratulations. You have just written and run your first program on the Micromite. If you type `EDIT` again you will be back in the editor where you can change or add to your program.

Flashing a LED

Connect a LED to pin 15 as shown in the diagram on the right.

Then use the `EDIT` command to enter the following program:

```
SETPIN 15, DOUT
DO
  PIN(15) = 1
  PAUSE 300
  PIN(15) = 0
  PAUSE 300
LOOP
```



When you have saved and run this program you should be greeted by the LED flashing on and off. It is not a great program but it does illustrate how your Micromite can interface to the physical world via your programming.

The chapter "Using the I/O pins" later in this manual provides a full description of the I/O pins and how to control them.

Setting the AUTORUN Option

You now have the Micromite doing something useful (if you can call flashing a LED useful). Assuming that this is all that you want the Micromite to do you can then instruct it to always run this program whenever power is applied.

To do this you first need to regain the command prompt and you can do this by entering CTRL-C at the console. This will interrupt the running program and return you to the command prompt.

Then enter the command:

```
OPTION AUTORUN ON
```

This instructs MMBasic to automatically run your program whenever power is applied. To test this you can remove the power and then re apply it. The Micromite should start up flashing the LED.

If this is all that you want you can disconnect the serial console and it will sit there flashing the LED on and off forever. If ever you wanted to change something (for example the pause between on and off) you can attach your terminal emulator to the console, interrupt the program with a CTRL-C and edit it as needed.

This is the great benefit of the Micromite, it is very easy to write and change a program.

Using MMBasic

Commands and Program Input

At the command prompt you can enter a command and it will be immediately run. Most of the time you will do this to tell the Micromite to do something like run a program or set an option. But this feature also allows you to test out commands at the command prompt.

To enter a program the easiest method is to use the EDIT command. This will invoke the full screen program editor which is built into the Micromite and is described later in this manual. It includes advanced features such as search and copy, cut and paste to and from a clipboard.

You could also compose the program on your desktop computer using something like Notepad and then transfer it to the Micromite via the XModem protocol (see the XMODEM command) or by streaming it up the console serial link (see the AUTOSAVE command).

A third and very convenient method of writing and debugging a program is to use MMEdit. This is a program running on your Windows or Linux computer which allows you to edit your program on your computer then transfer it to the Micromite with a single click of the mouse. MMEdit was written by Jim Hiley and can be downloaded for free from <http://www.c-com.com.au/MMEdit.htm>.

With all of these methods of entering and editing a program the result is saved in non volatile flash memory (this is transparent to the user). With the program held in flash memory it means that it will never be lost, even when the power is unexpectedly interrupted or the processor restarted.

One thing that you cannot do is use the old BASIC way of entering a program which was to prefix each line with a line number. Line numbers are optional in MMBasic so you can still use them if you wish but if you enter a line with a line number at the prompt MMBasic will simply execute it immediately.

Line Numbers, Program Structure and Editing

The structure of a program line is:

```
[line-number] [label:] command arguments [: command arguments] ...
```

A label or line number can be used to mark a line of code.

A label has the same specifications (length, character set, etc) as a variable name but it cannot be the same as a command name. When used to label a line the label must appear at the beginning of a line but after a line number (if used), and be terminated with a colon character (:).

Commands such as GOTO can use labels or line numbers to identify the destination (in that case the label does not need to be followed by the colon character). For example:

```
GOTO xxxx
- - -
xxxx: PRINT "We have jumped to here"
```

Multiple commands separated by a colon can be entered on the one line (as in INPUT A : PRINT B).

Running Programs

A program is set running by the RUN command. You can interrupt MMBasic and the running program at any time by typing CTRL-C on the console input and MMBasic will return to the command prompt.

You can list a program in memory with the LIST command. This will print out the program while pausing every 24 lines.

You can completely erase the program by using the NEW command.

A program in the Micromite is held in non volatile flash memory. This means that it will not be lost if the power is removed and, if you have the AUTORUN feature turned on, the Micromite will start by automatically running the program when power is restored (use the OPTION command to turn AUTORUN on).

Setting Options

Many options can be set by using commands that start with the keyword OPTION. They are listed in the commands section of this manual. For example, you can set the baud rate of the console with the command:

```
OPTION BAUDRATE 9600
```

Micromite Special Features

Saved Variables

Because the Micromite does not necessarily have a normal storage system (such as an SD card) it needs to have a facility to save some data that can be recovered when power is restored. This can be done with the VAR SAVE command which will save the variables listed on its command line in non volatile flash memory. The space reserved for saved variables is 2KB on the standard Micromite and 4K on the Micromite Plus.

These variables can be restored with the VAR RESTORE command which will add all the saved variables to the variable table of the running program. Normally this command is placed near the start of a program so that the variables are ready for use by the program.

This facility is intended for saving calibration data, user selected options and other items which change infrequently. It should not be used for high speed saves as you may wear out the flash memory.

The flash in the Micromite compatible chips has a very high endurance of over 20,000 writes and erases. With normal use this will never be reached but it can be exceeded by a program that repeatedly saves variables. For example, a program that saved a set of variables once a second would wear out the flash in six hours while a program that saved the same data once a day would run for over 50 years and still not wear out the flash.

If you do want to save data often it would be worth adding a real time clock chip to the Micromite design. The RTC SETREG and RTC GETREG commands can then be used to store and retrieve data from the RTC's battery backed memory. See the RTC command for more details. Another option is to use a Microchip 11XX series EEPROM which can be rewritten up to a million times. A driver for these is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

CPU Speed Control

MMBasic provides the ability to control the clock speed of the Micromite via the CPU command. The current drawn by the chip is proportional to the clock speed so this command can be used to balance the requirements of performance and low current drain. The default speed on power up or reset is 40MHz.

The available clock speeds and typical current draw are:

CPU Speed	Typical Current Draw
48 MHz	31 mA
40 MHz (default)	26 mA
30 MHz	21 mA
20 MHz	15 mA
10 MHz	10 mA
5 MHz	6 mA

The Micromite Plus can run up to 120 MHz. See the Micromite Plus Manual for more details.

When the clock speed is changed all the serial ports (including the console) will be unaffected although there may be a small glitch at the moment of change. The internal clocks and timers will also be unaffected. PWM, SPI and I²C will have their speeds changed proportionally so if this is not required they should be closed before the change and reopened after.

CPU Sleep

The CPU SLEEP command will put the processor to sleep for a certain number of seconds or monitor the WAKEUP pin for a wakeup signal. During sleep the current drain is less than 40 µA.

Normal use for the command is CPU SLEEP *seconds* and in that case the CPU will sleep for the specified number of seconds. The sleep time can be quite short (say 5 seconds) and, on waking up, the program can make a quick check and if there is nothing to do go back to sleep again. Because the time awake would be so short the average current drain would be small. Alternatively the sleep can be aborted early by a change in state of an I/O pin. Eg: CPU SLEEP *seconds, abortpin*

If the timeout is not specified this command will automatically configure the WAKEUP pin as a digital input. During sleep this pin will be monitored and the CPU woken up when its input changes state (ie, goes from high

to low or low to high). The wakeup signal could be a button press, an incoming signal or some other external interrupt. This form of wakeup is very fast ($< 1\text{ms}$).

In this mode the sleep function will also work with the IR command (for receiving key presses from a remote control) which shares the same I/O pin as the wakeup function. This means that an IR signal can be used to wakeup the Micromite which will then immediately decode the signal. The program can then do whatever it needs to do in response to the remote control key press then go back to sleep and wait for the next command.

Reducing Sleep Current

The sleep current can be affected by many factors other than the base sleep current (which can be as low as $40\mu\text{A}$). These are some of the factors to consider:

- Don't leave I/O pins floating. If an I/O pin is not held high or low by external circuitry set it to an output.
- Disconnect the console.
- I/O pins will still source or sink current, even in sleep. Before entering sleep make sure that all I/O pins are in a state that will not do this.
- Close any communications channels that are open. This especially includes serial and I²C.
- Stop any PWM or SERVO outputs.
- Disable any I/O pins that are used for measuring frequency, period and/or counting.

If you are having difficulty achieving a low sleep current consider connecting a Micromite into a simple circuit with nothing attached and set all I/O pins to digital outputs. Use NEW to clear the program memory and measure the current drawn when CPU SLEEP is entered at the command prompt and the console disconnected. This is the target current draw (it should be around $40\mu\text{A}$) and you can then measure the effect as you add external circuitry and software features.

Watchdog Timer

The main use for the Micromite is as an embedded controller. It can be programmed in MMBasic and when the program is debugged and ready for "prime time" the AUTORUN configuration setting can be turned on. The chip will then automatically run its program when power is applied and act as a custom integrated circuit performing some special task. The user need not know anything about what is running inside the chip.

However there is the possibility that a fault in the program could cause MMBasic to generate an error and return to the command prompt. This would be of little use in an embedded situation as the Micromite would not have anything connected to the console. Another possibility is that the BASIC program could get itself stuck in an endless loop for some reason. In both cases the visible effect would be the same... the program would stop running until the power was cycled.

To guard against this the watchdog timer can be used. This is a timer that counts down to zero and when it reaches zero the processor will be automatically restarted (the same as when power was first applied), this will occur even if MMBasic was sitting at the command prompt. Following the restart the automatic variable MM.WATCHDOG will be set to true to indicate that the restart was caused by a watchdog timeout.

The WATCHDOG command should be placed in strategic locations in the program to keep resetting the timer and therefore preventing it from counting down to zero. Then, if a fault occurs, the timer will not be reset, it will count down to zero and the program will be restarted (assuming the AUTORUN option is set).

PIN Security

Sometimes it is important to keep the data and program in an embedded controller confidential. In the Micromite this can be done by using the OPTION PIN command. This command will set a pin number (which is stored in flash) and whenever the Micromite returns to the command prompt (for whatever reason) the user at the console will be prompted to enter the PIN number. Without the correct PIN the user cannot get to the command prompt and their only option is to enter the correct PIN or reboot the Micromite. When it is rebooted the user will still need the correct PIN to access the command prompt.

Because an intruder cannot reach the command prompt they cannot list or copy a program, they cannot change the program or change any aspect of MMBasic or the Micromite. Once set the PIN can only be removed by providing the correct PIN as set in the first place. If the number is lost the only method of recovery is to reset MMBasic as described below (which will erase the program).

There are other time consuming ways of accessing the data (such as using a PIC32 programmer to examine the flash memory) so this should not be regarded as the ultimate security but it does act as a significant deterrent.

The Serial Console

Using the `OPTION BAUDRATE` command the baud rate of the console can be changed to any speed up to 230400 bps. Changing the console baud rate to a higher speed makes the full screen editor much faster in redrawing the screen. If you have a reliable connection to the Micromite it is worth changing the speed to at least 115200.

Once changed the console baud rate will be permanently remembered unless another `OPTION BAUDRATE` command is used to change it. Using this command it is possible to accidentally set the baud rate to an invalid speed and in that case the only recovery is to reset MMBasic as described below.

When running as an embedded controller the serial console may no longer be required for programming. On the standard Micromite it can then be used as a third serial port and `OPTION BAUDRATE` used to set the required speed. If you do this it might be worth using the `OPTION BREAK` command to disable the break key to prevent an unintended `CTRL-C` in the console receive data from halting the running program.

Other useful options are `OPTION CONSOLE NOECHO` which will stop MMBasic from automatically echoing characters received on the console and `OPTION CONSOLE INVERT` which will invert the data on the transmit and receive lines so that it can be used with RS232 devices.

Resetting MMBasic

MMBasic can be reset to its original configuration using either one of two methods:

- The chip can be reprogrammed with the Micromite firmware using a PIC32 programmer.
- Sending a stream of exclamation marks (!) to the console Rx pin at 38400 baud during its startup. In the first 100 ms after powering up the Micromite will set the console to 38400 baud and check to see if an exclamation mark is received. If so, it will then wait for two seconds to see if it is going to get more than 30 of them in that time. If this is the case the Micromite will reset itself to its initial defaults and send the message "MMBasic reset completed" to the console.
This reset can be accomplished by simply setting the terminal emulator to 38400 baud and holding down the exclamation key and rely on the automatic keyboard repeat while powering up the Micromite (on most keyboards this requires holding down shift and the number one key). This will even work if the console has been set to a non standard baud rate.

Either method will result in the program memory and saved variables being completely erased and all options (security PIN, console baud rate, etc) will be reset to their initial defaults.

Single, Secure HEX File

If you write a program for the Micromite and set the following options:

```
OPTION BREAK 0
OPTION AUTORUN ON
```

you will end up with a program that cannot be stopped or interrupted. To further bullet proof it you could use the watchdog timer and `OPTION PIN`.

You can then use a PICKit3 and MPLAB IPE to read the complete flash memory of the Micromite and export it as a hex file. This will contain the Micromite firmware as well as your BASIC program and the above options.

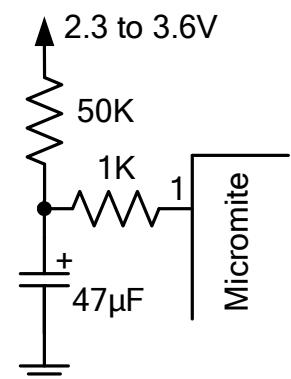
This file can be sent to someone as custom firmware for a compatible PIC32 chip. They can load the hex file and it will immediately start running your program. To them it will be indistinguishable from firmware written in C (other than the startup banner produced by MMBasic). They do not have to load MMBasic and they do not need know anything about programming for the Micromite.

Delayed Start Up

The Micromite will start up in about 100ms but in some cases it might be necessary to delay the start up to allow other circuitry (such as a USB-to-serial bridge) to start up first.

This can be accomplished by delaying the rising edge of the voltage on pin 1 (on the 28-pin chip) or 18 (on the 44-pin chip) which will have the effect of holding the Micromite in reset. A suitable circuit is shown on the right. The delay is set by the combination of the 50K resistor and the 47 μ F capacitor and, with the values shown, will delay start up by about 350ms.

The 1K resistor is there to ensure the safe discharge of the 47 μ F capacitor when the power is removed.



LCD Displays

The standard Micromite includes support for colour LCD display panels using the ILI9341 controller and an SPI interface. These have a 240x320 pixel colour TFT display, come in a variety of sizes (2.2", 2.4" and 2.8") and are low cost (typically US\$8). The Micromite Plus also supports this display in addition to many more ranging in size from 1.44" to 8". See the Micromite Plus Manual for more details.

On eBay you can find suitable displays by searching for the controller name (ILI9341).

There are many similar displays on the market however some have subtle differences that could prevent them from working with the Micromite. MMBasic was tested with the displays illustrated below so, if you wish to guarantee success make sure your display matches the photographs and the specifications listed below.

The ILI9341 based displays use an SPI interface and have the following basic specifications:

- A 2.2, 2.4 or 2.8 inch display
- Resolution of 240 x 320 pixels and a colour depth of 262K/65K
- A ILI9341 controller with a SPI serial interface

The display illustrated also has a touch sensitive facility which is fully supported by MMBasic. There are versions of this display without the touch controller (the 16-pin IC on the bottom right of the PCB) but there is not much point in purchasing these as the price difference is small.

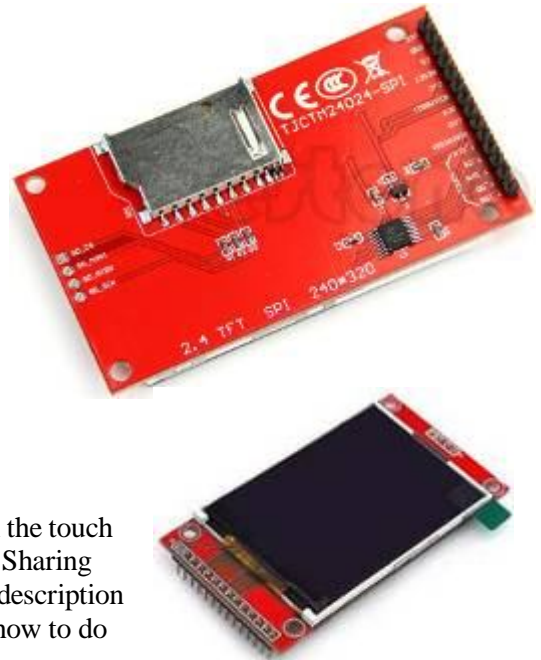
Be aware that some eBay sellers show a photo of the board with the touch controller but further down the listing state that their product does not support touch.

Connecting SPI Based LCD Panels

The SPI based display controllers share the Micromite's SPI interface with the touch controller (if present) and the BASIC program running on the Micromite. Sharing the SPI channel is essentially transparent to the BASIC program – see the description of the SPI communications function in Appendix D for an explanation of how to do this.

The following table lists the connections required between the LCD display board and the Micromite:

ILI9341 Display	Description	28-pin Micromite	44-pin Micromite
T_IRQ	Touch Interrupt	Configurable	
T_DO	Touch Data Out (MISO)	Pin 14	Pin 41
T_DIN	Touch Data In (MOSI)	Pin 3	Pin 20
T_CS	Touch Chip Select	Configurable	
T_CLK	Touch SPI Clock	Pin 25	Pin 14
SDO (MISO)	Display Data Out (MISO)	Pin 14	Pin 41
LED	Power supply for the backlight (see below)		
SCK	Display SPI Clock	Pin 25	Pin 14
SDI (MOSI)	Display Data In (MOSI)	Pin 3	Pin 20
D/C	Display Data/Command Control	Configurable	
RESET	Display Reset (when pulled low)	Configurable	
CS	Display Chip Select	Optional - Configurable	
GND	Ground		
VCC	5V supply (the controller draws less than 10 mA)		



Note: Be careful to ground yourself when handling the display as the ILI9341 controller is sensitive to static discharge and can easily be destroyed.

Where a Micromite connection is listed as "configurable" the specific pin should be specified with the OPTION LCDPANEL or OPTION TOUCH commands (see below).

The backlight power (the LED connection) should be supplied from the main 5V supply via a current limiting resistor. A typical value for this resistor is 18Ω which will result in a LED current of about 63 mA. The value of this resistor can be varied to reduce the power consumption or to provide a brighter display.

Important: Care must be taken with display panels that share the SPI port between a number of devices (display controller, touch, etc). In this case all the Chip Select signals must be configured in MMBasic or disabled by a permanent connection to 3.3V. If this is not done any unconnected Chip Select pins will float causing the wrong controller to respond to commands on the SPI bus.

Configuring MMBasic

To use the display MMBasic must be configured using the OPTION LCDPANEL command which must be entered at the command prompt (not in a program).

The syntax is:

```
OPTION LCDPANEL ILI9341, orientation, D/C pin, reset pin [,CS pin]
```

Where:

'orientation' can be LANDSCAPE, PORTRAIT, RLANDSCAPE or RPORTRAIT. These can be abbreviated to L, P, RL or RP. The R prefix indicates the reverse or "upside down" orientation.

'D/C pin' and 'reset pin' are the Micromite I/O pins to be used for these functions. Any free pin can be used.

'CS pin' can also be any free I/O pin but is optional. If a touch controller is not used this parameter can be left off the command and the CS pin on the LCD display wired permanently to ground. If the touch controller is used this pin must then be specified and connected to a Micromite I/O pin.

As an example, this is the command that will configure the Micromite for the display used in the Micromite LCD Backpack project:

```
OPTION LCDPANEL ILI9341, L, 2, 23, 6
```

This command only needs to be run once. From then on MMBasic will automatically initialise the display on startup or reset. In some circumstances it may be necessary to interrupt power to the LCD panel while the Micromite is running (eg, to save battery power) and in that case the GUI RESET LCDPANEL command can be used to reinitialise the display the same as in power up.

If the LCD panel is no longer required the command OPTION LCDPANEL DISABLE can be used which will return the I/O pins for general use.

To test the display you can enter the command GUI TEST LCDPANEL. You should see an animated display of colour circles being rapidly drawn on top of each other. Press the space key on the console's keyboard to stop the test.

Important: The above test may not work if the display has a touch controller and the touch controller has not been configured (ie, the touch Chip Select pin is floating). In this case configure the touch controller (see below) and then retry GUI TEST LCDPANEL.

NOTE: The CPU speed must be 20 MHz or greater.

To verify the configuration you can use the command OPTION LIST to list all options that have been set including the configuration of the LCD panel.

Loadable Drivers

You can use a loadable driver to add full support for LCD panels using other controllers. These drivers are located in the CFunctions subdirectory in the firmware distribution zip file. See the documentation accompanying the driver for details of how to connect the LCD panel and configure the driver.

Touch Support

Most ILI9341 based LCD panels are supplied with a resistive touch sensitive panel and associated controller chip. To use the touch feature in MMBasic the touch controller must first be connected to the Micromite (see the above chapter for the details) and then configured (see below).

Configuring Touch

To use the touch facility MMBasic must be configured using the `OPTION TOUCH` command at the command prompt (not in a program). This should be done after the LCD panel has been configured (see above).

The syntax is:

```
OPTION TOUCH T_CS pin, T_IRQ pin
```

Where:

'T_CS pin' and 'T_IRQ pin' are the Micromite I/O pin numbers to be used for chip select and touch interrupt respectively (any free pins can be used).

This command only needs to be run once as the parameters are stored in non volatile memory. Every time the Micromite is restarted MMBasic will automatically initialise the touch controller.

If the touch facility is no longer required use the command `OPTION TOUCH DISABLE` to disable the touch feature and return the I/O pins for general use (the 'T_CS pin' should be held high to disable the controller).

Calibrating the Touch Screen

Before the touch facility can be used it must be calibrated using the `GUI CALIBRATE` command.

This command will present a target in the top left corner of the screen. Using a pointy but blunt object such as a toothpick press exactly on the centre of the target and hold it down for at least a second. MMBasic will record this location and then continue the calibration by sequentially displaying the target in the other three corners of the screen for touch and calibration.

The calibration routine may warn that the calibration was not accurate. This is just a warning and you can still use the touch feature if you wish but it would be better to repeat the calibration using more care.

Following calibration you can test the touch facility using the `GUI TEST TOUCH` command. This command will blank the screen and wait for a touch. When the screen is touched a white dot will be placed on the display marking the position on the screen. If the calibration was carried out successfully the dot should be displayed exactly under the location of the stylus on the screen.

To exit the test routine you can press the space bar on the console's keyboard.

Touch Functions

To detect if and where the screen is touched you can use the following functions in a BASIC program:

- `TOUCH(X)`
Returns the X coordinate of the currently touched location.
- `TOUCH(Y)`
Returns the Y coordinate of the currently touched location.

Both functions return -1 if the screen is not being touched. The Micromite Plus also provides a number of additional functions. See the Micromite Plus Manual for more details.

Touch Interrupts

An interrupt can be set on the IRQ pin number that was specified when the touch facility was configured. To detect touch down the interrupt should be configured as INTL (ie, high to low).

For example, if the command `OPTION TOUCH 7, 15` was used to configure touch the following program will print out the X and Y coordinates of any touch on the screen:

```
SETPIN 15, INTL, MyInt
DO : LOOP

SUB MyInt
  PRINT TOUCH(X) TOUCH(Y)
END SUB
```

The interrupt can be cancelled with the command `SETPIN pin, OFF`.

Using an LCD Panel

There are eight basic drawing commands that you can use within MMBasic programs on the Micromite to interact with an attached LCD display. The Micromite Plus also supports these plus a series of more powerful GUI commands. See the Micromite Plus Manual for more details.

All coordinates and measurements on the screen are done in terms of pixels with the X coordinate being the horizontal position and Y the vertical position. The top left corner of the screen has the coordinates X=0 and Y=0 and the values increase as you move down and to the right of the screen.

Read Only Variables

There are four read only variables which provide useful information about the display currently connected:

- **MM.HRES**
Returns the width of the display (the X axis) in pixels.
- **MM.VRES**
Returns the height of the display (the Y axis) in pixels.
- **MM.FONTHEIGHT**
Returns the height of the current default font (in pixels). All characters in a font have the same height.
- **MM.FONTWIDTH**
Returns the width of a character in the current default font (in pixels). All characters in a font have the same width.

Colours

Colour is specified as a true colour 24 bit number where the top eight bits represent the intensity of the red colour, the middle eight bits the green intensity and the bottom eight bits the blue. The easiest way to generate this number is with the RGB() function which has the form:

```
RGB(red, green, blue)
```

A value of zero for a colour represents black and 255 represents full intensity. The RGB() function also supports a shortcut where you can specify common colours by naming them. For example, RGB(red) or RGB(cyan). The colours that can be named using the shortcut form are white, black, blue, green, cyan, red, magenta, yellow, brown and gray.

MMBasic will automatically translate all colours to the format required by the individual display controller which, in the case of the ILI9341 controller, is 64K colours in the 565 format.

Note that the 24 bit number representing colour (ie, returned by the RGB() function) is too large to be accurately stored in a floating point variable, instead the variable should be declared as an integer. Similarly, arguments should be declared as integer if you are passing a colour value to a subroutine or function.

The default for commands that require a colour parameter can be set with the COLOUR command. This handy if your program uses a consistent colour scheme, you can then set the defaults and use the short version of the drawing commands throughout your program.

The COLOUR command takes the format:

```
COLOUR foreground-colour, background-colour
```

Fonts

MMBasic for the 28 and 44-pin Micromites includes one built in font which is 8 pixels wide by 13 pixels high and includes all 95 standard ASCII characters with the back quote character (60 hex or 96 decimal) replaced with the degree symbol (°). Within MMBasic this is referred to as font #1. The Micromite Plus has six built in fonts (refer to the Micromite Plus Manual for more details).

If required, additional fonts can be embedded in a BASIC program. The MMBasic firmware zip file includes over a dozen fonts covering a wide range of character sets including a symbol font (Dingbats) which is handy for creating on screen icons, etc. These fonts work exactly same as the built in font (ie, selected using the FONT command or specified in the TEXT command).

The format of an embedded font is:

```
DefineFont #Nbr
    hex [[ hex[...]]
    hex [[ hex[...]]
END DefineFont
```

It must start with the keyword "DefineFont" followed by the font number (which may be preceded by an optional # character). Any font number in the range of 1 to 16 can be specified. The body of the font is a sequence of 8-digit hex words with each word separated by one or more spaces or a new line. The font definition is terminated by an "End DefineFont " keyword.

When a BASIC program is saved to program memory MMBasic will search through it looking for any embedded fonts and the font table will be updated to include them. During execution embedded fonts will be skipped over and this means that they can be placed anywhere in the program.

Embedded fonts can also be saved to the library area. When this is done the font is, for all intent and purposes, permanently added to the MMBasic language. In addition MMBasic will strip out the hex codes in the font definition (because they are no longer needed) and this will save a considerable amount of memory. See the LIBRARY command for details on how to use the library.

The default font used by MMBasic is font #1 however that can be changed with the FONT command:

```
FONT font-number, scaling
```

Where 'font-number' is a number which can be optionally preceded by a hash (#) character. 'scaling' is optional and is a number in the range of 1 to 15. The font will be multiplied by the scaling factor making the displayed character correspondingly wider and taller. For example, specifying 'scaling' of 2 will double the height and width. If not specified the scaling factor will be 1 (ie, no scaling).

Drawing Commands

Most drawing commands have optional parameters. You can completely leave these off the end of a command or you can use two commas in sequence to indicate a missing parameter. For example, the fifth parameter of the LINE command is optional so you can use this format:

```
LINE 0, 0, 100, 100, , rgb(red)
```

Optional parameters are indicated below by italics, for example: *font*.

In the following commands C is the drawing colour and defaults to the current foreground colour. FILL is the fill colour which defaults to -1 which indicates that no fill is to be used.

The drawing commands are:

- `CLS C`
Clears the screen to the colour C. If C is not specified the current default background colour will be used.
- `PIXEL X, Y, C`
Illuminates a pixel. If C is not specified the current default foreground colour will be used.
- `LINE X1, Y1, X2, Y2, LW, C`
Draws a line starting at X1 and Y1 and ending at X2 and Y2.
LW is the line's width and is only valid for horizontal or vertical lines. It defaults to 1 if not specified or if the line is a diagonal.
- `BOX X, Y1, W, H, LW, C, FILL`
Draws a box starting at X and Y1 which is W pixels wide and H pixels high.
LW is the width of the sides of the box and can be zero. It defaults to 1.
- `RBOX X, Y1, W, H, R, C, FILL`
Draws a box with rounded corners starting at X and Y1 which is W pixels wide and H pixels high.
R is the radius of the corners of the box. It defaults to 10.
- `CIRCLE X, Y, R, LW, A, C, FILL`
Draws a circle with X and Y as the centre and a radius R. LW is the width of the line used for the circumference and can be zero (defaults to 1). A is the aspect ratio which is a floating point number and defaults to 1. For example, an aspect of 0.5 will draw an oval where the width is half the height.
- `TEXT X, Y, STRING, ALIGNMENT, FONT, SCALE, C, BC`
Displays a string starting at X and Y. ALIGNMENT is 0, 1 or 2 characters (a string expression or variable is also allowed) where the first letter is the horizontal alignment around X and can be L, C or R for LEFT, CENTER or RIGHT aligned text and the second letter is the vertical alignment around Y and can be T, M or B for TOP, MIDDLE or BOTTOM aligned text. The default alignment is left/top. The Micromite Plus can also use an additional code letter to rotate the text (see the *Micromite Plus Manual* for the details). FONT and SCALE are optional and default to that set by the FONT command. C is the drawing colour and BC is the background colour. They are optional and default to that set by the COLOUR command.

□ GUI BITMAP X, Y, BITS, WIDTH, HEIGHT, SCALE, C, BC

Displays the bits in a bitmap starting at X and Y. HEIGHT and WIDTH are the dimensions of the bitmap as displayed on the LCD panel and default to 8x8. SCALE, C and BC are the same as for the TEXT command. The bitmap can be an integer or a string variable or constant and is drawn using the first byte as the first bits of the top line (bit 7 first, then bit 6, etc) followed by the next byte, etc. When the top line has been filled the next line of the displayed bitmap will start with the next bit in the integer or string.

Example

As an example the following program will draw a simple digital clock on an ILI9341 based LCD display. The program will terminate and return to the command prompt if the display screen is touched.

First the display and touch options must be configured by entering commands similar to these at the command prompt:

```
OPTION LCDPANEL ILI9341, L, 2, 23, 6
OPTION TOUCH 7, 15
```

These settings specify an ILI9341 based display in the landscape orientation and uses pins 2, 23 and 6 for the LCD and pins 7 and 15 for the touch controller (all on the 28-pin Micromite). They suit the Micromite LCD Backpack (see next chapter) but your configuration could be different.

Next the touch feature should be calibrated by entering this command and following the calibration procedure.

```
GUI CALIBRATE
```

Finally you can enter and run the program:

```
CONST DBlue = RGB(0, 0, 128)           ' A dark blue colour
COLOUR RGB(GREEN), RGB(BLACK)         ' Set the default colours
FONT 1, 3                             ' Set the default font

BOX 0, 0, MM.HRes-1, MM.VRes/2, 3, RGB(RED), DBlue

DO
  TEXT MM.HRes/2, MM.VRes/4, TIMES$, "CM", 1, 4, RGB(CYAN), DBlue
  TEXT MM.HRes/2, MM.VRes*3/4, DATE$, "CM"
  IF TOUCH(X) <> -1 THEN END
LOOP
```

The program starts by defining a constant with a value corresponding to a dark blue colour and then sets the defaults for the colours and the font. It then draws a box with red walls and a dark blue interior.

Following this the program enters a continuous loop where it performs three functions:

1. Displays the current time inside the previously drawn box. The string is drawn centred both horizontally and vertically in the middle of the box. Note that the TEXT command overrides both the default font and colours to set its own parameters.
2. Draws the date centred in the lower half of the screen. In this case the TEXT command uses the default font and colours previously set.
3. Checks for a touch on the screen. This is indicated when the TOUCH(X) function returns something other than -1. In that case the program will terminate.

The screen display should look like this (the font used in this illustration is different):



Micromite LCD Backpack

The Micromite LCD Backpack is a popular project which combines the 28-pin Micromite with a touch sensitive LCD panel using the ILI9341 controller.

The PCB carrying the Micromite is designed to piggy back onto the LCD panel making a neat two board sandwich which can be used as the core of many projects that require an easily programmable microcontroller with a colourful touch sensitive LCD display as the user interface.

With less than a dozen components the Micromite LCD Backpack can be built in under half an hour.

The Micromite LCD Backpack is described on this web page: <http://geoffg.net/MicromiteBackpack.html>

And there are currently four projects on the Micromite website which are based on it. These are the:

Parking Assistant: <http://geoffg.net/ParkingAssistant.html>

Boat Computer: <http://geoffg.net/BoatComputer2.html>

Super Clock: <http://geoffg.net/SuperClock.html>

DDS Signal Generator: <http://geoffg.net/SignalGenerator.html>

This chapter of the manual is intended to provide a "fast start" for people who have built the backpack and just want to quickly get it going.

Programming MMBasic into the PIC32

When construction of the backpack is completed the first task is to program the PIC32 microcontroller with the Micromite firmware. This includes the BASIC interpreter and management software.

There are two ways to do this depending on the version of the Micromite LCD Backpack that you have:

Micromite LCD Backpack Version 1

This version of the backpack requires that you use an external programmer. The best programmer for the job is a cheap clone of the PICKit3. See this page for a full description: http://geoffg.net/programming_pics.html

The backpack PCB has a six pin connector labelled ICSP which is designed to mate with the PICKit3 programmer as shown in the photo.



Micromite LCD Backpack Version 2

This version of the backpack has its own built in PIC32 programmer using a suitably programmed PIC16F1455 microcontroller (dubbed the "Microbridge"). This page describes the Microbridge and how to transfer the firmware to it for programming into the PIC32: <http://geoffg.net/microbridge.html>

The Micromite firmware comes as a file with an extension of .hex. You should download the latest version from: <http://geoffg.net/micromite.html#Downloads> and use the above method to program it into the PIC32.

Connecting to the Console

The next task is to connect a terminal emulator to the Micromite's console. The console is a serial interface over which you can issue commands to configure the chip, load the BASIC program and run it. MMBasic also uses the console to display error messages. Again, how you do this varies depending on the version of the Micromite LCD Backpack that you have:

Micromite LCD Backpack Version 1

For this version you will need a USB to serial converter which plugs into a USB port on your desktop computer and at the other end connects to the Micromite's serial console. From your computer's point of view it will look like a serial port (via USB) while the connection to the Micromite Plus is a standard serial interface with TTL signals levels. The full description of this process is provided earlier in this manual. Look for the chapter labelled "Console Connection".

Micromite LCD Backpack Version 2

This version has its own built in USB to serial converter using the PIC16F1455 microcontroller which also acted as the PIC32 programmer ("Microbridge"). See <http://geoffg.net/microbridge.html> for more details.

Configuring MMBasic

With the console connected you should have access to the console and the command prompt ">". You then need to configure the Micromite for the LCD and touch connections to suit the Micromite LCD Backpack. To do this you should issue the following commands at the command prompt:

```
OPTION LCDPANEL ILI9341, L, 2, 23, 6
OPTION TOUCH 7, 15
```

You then need to calibrate the touch panel using this command:

```
GUI CALIBRATE
```

This will cause MMBasic to draw a sequence of four targets (the first is shown on the right). Using a pointy but blunt object (eg, a toothpick) press on the exact centre of the target and MMBasic will step onto the next target and so on until all four targets have been processed.

The full details of these setup commands are described in the previous chapters of this manual.



Loading the BASIC program

Loading BASIC code into the Micromite is done over the console using either the AUTOSAVE or XMODEM commands. This requires you to have a terminal emulator running on your desktop machine and connected to the console of the Micromite.

The AUTOSAVE command puts the Micromite into a mode where anything received on the console will be saved to the program memory. This means that you can simply copy the text and paste it into the terminal emulator (eg, Tera Term) which will send it to the Micromite. From the Micromite's perspective pasting text into the terminal emulator is the same as if a high speed typist was typing in the program. To terminate the AUTOSAVE command you need to press the Control-Z keys in the terminal emulator and the Micromite will save the program to flash memory and return to the command prompt.

The XMODEM command is a little more sophisticated, it uses the XModem protocol to transfer the data including an integrity check. The full command is:

```
XMODEM RECEIVE
```

This instructs the Micromite to look for an XModem connection on the console. After running this command you should then instruct your terminal emulator to send the file using the XModem protocol. In Tera Term this is done by using the following menu selection:

File->Transfer->XMODEM->Send

When the complete file has been sent the Micromite will save it in program memory and return to the command prompt.

Saving Fonts in the Library

Some programs require that you load the fonts separately and save them to the library. The library is a special area in the Micromite where fonts and program modules can be stored (see the chapter "Special Functions and the Library" later in this manual). MMBasic will compress the data in the library which is why some programs need to use the library. If the program that you are loading has a separate font file load that first, then use the command LIBRARY SAVE. That will transfer the code to the library and delete it from main memory.

Finally you can load the main BASIC program and start it by entering the command RUN.

Special Device Support

To make it easier for a program to interact with the external world the Micromite includes drivers for a number of common peripheral devices.

These are:

- Infrared remote control receiver and transmitter
- The DS18B20 temperature sensor and DHT22 temperature/humidity sensor
- LCD display modules
- Numeric keypads
- Battery backed clock
- Servos
- Ultrasonic distance sensor

Infrared Remote Control Decoder

You can easily add a remote control to your project using the IR command. When enabled this function will run in the background and interrupt the running program whenever a key is pressed on the IR remote control.

It will work with any NEC or Sony compatible remote controls including ones that generate extended messages. Most cheap programmable remote controls will generate either protocol and using one of these you can add a sophisticated flair to your Micromite based project. The NEC protocol is also used by many other manufacturers including Apple, Pioneer, Sanyo, Akai and Toshiba so their name brand remotes can be used.

To detect the IR signal you need an IR receiver connected to the IR pin (pin 16 on a 28-pin chip) as illustrated in the diagram. The IR receiver will sense the IR light, demodulate the signal and present it as a TTL voltage level signal to this pin. Setup of the I/O pin is automatically done by the IR command.

NEC remotes use a 38kHz frequency and suitable receivers tuned to that frequency include the Vishay TSOP4838, Jaycar ZD1952 and Altronics Z1611A .

Sony remotes use a 40kHz frequency but receivers for that frequency can be hard to find. Generally 38 kHz receivers will work but maximum sensitivity will be achieved with a 40kHz receiver.

To setup the decoder you use the command:

```
IR dev, key, interrupt
```

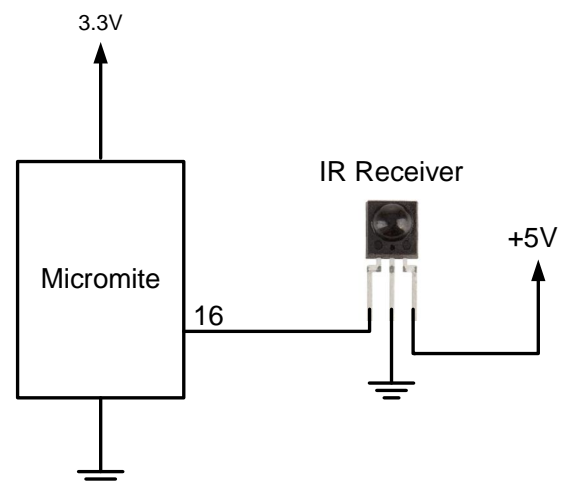
Where dev is a variable that will be updated with the device code and key is the variable to be updated with the key code. Interrupt is the interrupt subroutine to call when a new key press has been detected. The IR decoding is done in the background and the program will continue after this command without interruption.

This is an example of using the IR decoder:

```
IR DevCode, KeyCode, IR_Int      ' start the IR decoder
DO
  ' < body of the program >
LOOP

SUB IR_Int                        ' a key press has been detected
  PRINT "Received device = " DevCode " key = " KeyCode
END SUB
```

IR remote controls can address many different devices (VCR, TV, etc) so the program would normally examine the device code first to determine if the signal was intended for the program and, if it was, then take action based on the key pressed. There are many different devices and key codes so the best method of determining what codes your remote generates is to use the above program to discover the codes.



The IR function uses the same I/O pin as the wakeup signal for the CPU SLEEP command and it is possible to combine them so that an incoming IR signal will wake the Micromite which will then decode the IR signal. In this way you can have a Micromite running on battery power that will wake up on an IR signal, do something based on the signal, then go back to sleep.

The following is an example:

```

IR DevCode, KeyCode, IR_Int      ' start the IR decoder
DO
    CPU SLEEP                     ' now sleep until a signal
LOOP

SUB IR_Int                        ' a key press has been detected
    < do some work based on the key press >
END SUB                          ' return to sleep again

```

Infrared Remote Control Transmitter

Using the IRSEND command you can transmit a 12 bit Sony infrared remote control signal. This is intended for Micromite to Micromite communications but it will also work with Sony equipment that uses 12 bit codes. Note that all Sony products require that the message be sent three times with a 26 ms delay between each message.

In previous versions of the Micromite firmware this command was built into MMBasic but now it is distributed as a CSub module which works exactly the same. See the file *IRSend.pdf* which is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

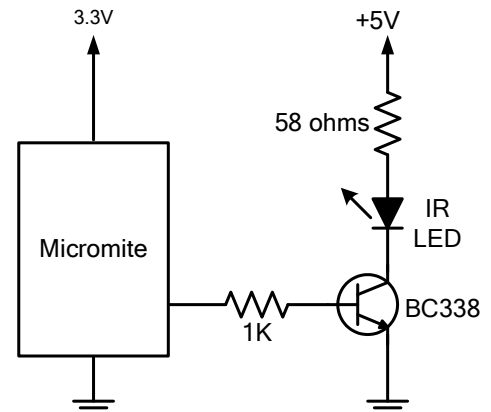
The circuit on the right illustrates what is required. The transistor is used to drive the infrared LED because the output of the Micromite is limited to about 10mA. This circuit provides about 50mA to the LED.

To send a signal you use the command:

```
IRSEND pin, dev, key
```

Where pin is the I/O pin used, dev is the device code to send and key is the key code. Any I/O pin on the Micromite can be used and you do not have to set it up beforehand (IRSEND will automatically do that).

The modulation frequency used is 38 kHz and this matches the common IR receivers (described in the previous page) for maximum sensitivity when communicating between two Micromites.



Measuring Temperature

The TEMPR() function will get the temperature from a DS18B20 temperature sensor. This device can be purchased on eBay for about \$5 in a variety of packages including a waterproof probe version.

The DS18B20 can be powered separately by a 3V to 5V supply or it can operate on parasitic power from the Micromite as shown on the right. Multiple sensors can be used but a separate I/O pin and a 4.7K pullup resistor is required for each one.

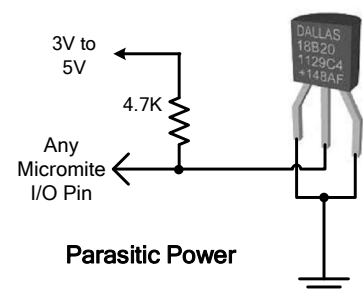
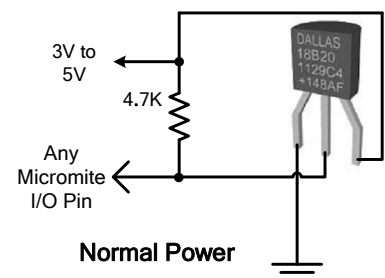
To get the current temperature you just use the TEMPR() function in an expression. For example:

```
PRINT "Temperature: " TEMPR(pin)
```

Where 'pin' is the I/O pin to which the sensor is connected. You do not have to configure the I/O pin, that is handled by MMBasic.

The returned value is in degrees C with a resolution of 0.25°C and is accurate to ±0.5°C. If there is an error during the measurement the returned value will be 1000.

The time required for the overall measurement is 200ms and the running program will halt for this period while the measurement is being made. This also means that interrupts will be disabled for this period. If you do not want this you can separately trigger the conversion using the TEMPR START



command then later use the TEMPR() function to retrieve the temperature reading. The TEMPR() function will always wait if the sensor is still making the measurement.

For example:

```
TEMPR START 15
< do other tasks >
PRINT "Temperature: " TEMPR(15)
```

Measuring Humidity and Temperature

The HUMID command will read the humidity and temperature from a DHT22 humidity/temperature sensor. This device is also sold as the RHT03 or AM2302 but all are compatible and can be purchased on eBay for under \$5.

In previous versions of the Micromite firmware this command was built into MMBasic but now it is distributed as a CSub module which works the same. See the file *Humid.pdf* which is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

The DHT22 can be powered from 3.3V or 5V (5V is recommended) and it should have a pullup resistor on the data line as shown. This is suitable for long cable runs (up to 20 meters) but for short runs the resistor can be omitted as the Micromite also provides an internal weak pullup.

To get the temperature or humidity you use the HUMID command with three arguments as follows:

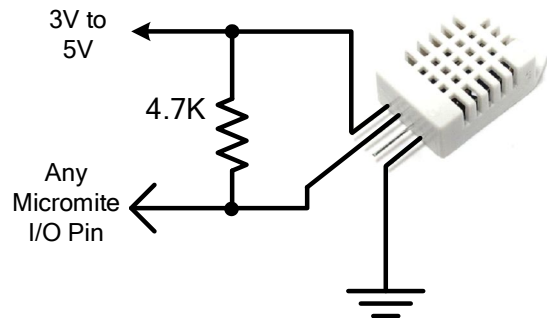
```
HUMID pin, tVar, hVar
```

Where 'pin' is the I/O pin to which the sensor is connected. You can use any I/O pin but if the DHT22 is powered from 5V it must be 5V capable. The I/O pin will be automatically configured by MMBasic.

'tVar' is a floating point variable in which the temperature is returned and 'hVar' is a second variable for the humidity. Both of these variables must be declared first as floats (using DIM). The temperature is returned as degrees C with a resolution of one decimal place (eg, 23.4) and the humidity is returned as a percentage relative humidity (eg, 54.3).

For example:

```
DIM FLOAT temp, humidity
HUMID pin, temp, humidity
PRINT "The temperature is" temp " and the humidity is" humidity
```



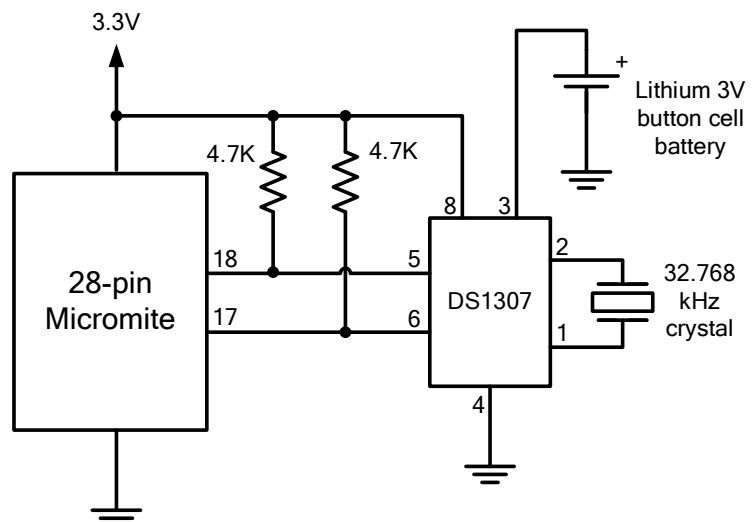
Real Time Clock Interface

Using the RTC GETTIME command it is easy to get the current time from a PCF8563, DS1307, DS3231 or DS3232 real time clock as well as compatible devices such as the M41T11. These integrated circuits are popular and cheap, will keep accurate time even with the power removed and can be purchased for \$2 to \$8 on eBay. Complete modules including the battery can also be purchased on eBay for a little more.

The PCF8563 and DS1307 will keep time to within a minute or two over a month while the DS3231 and DS3232 are particularly precise and will remain accurate to within a minute over a year.

These chips are I²C devices and should be connected to the I²C I/O pins of the Micromite. This circuit shows a typical circuit for the DS1307. The other chips have similar circuits (check their data sheets).

Internal pullup resistors (100K Ω) are applied to the I²C I/O pins so in many cases external resistors (as shown in the diagram) are not needed.



Before you can use the chip its time must be first set. That is done with the RTC SETTIME command which uses the format RTC SETTIME year, month, day, hour, minute, second. Note that the hour must be in 24 hour format.

For example, the following will set the real time clock to 4PM on the 10th November 2016:

```
RTC SETTIME 2016, 11, 10, 16, 0, 0
```

To get the time you use the RTC GETTIME command which will read the time from the real time clock chip and set the clock inside the Micromite. Normally this command will be placed at the beginning of the program or in the subroutine MM.STARTUP so that the time is set on power up.

The clock in the standard 28 and 44-pin Micromite can drift by up to two or three seconds in an hour so to keep it accurate over a long period the RTC can be polled at regular intervals using the SETTICK command.

For example:

```
RTC GETTIME                                ' set the time at startup
SETTICK 12 * 3600000, SetTime, 4           ' interrupt every 12 hours
< normal program >

SUB SetTime                                ' interrupt called every 12 hours
    RTC GETTIME                            ' reset the time
END SUB
```

Measuring Distance

Using a HC-SR04 ultrasonic sensor and the DISTANCE() CFunction you can measure the distance to a target. This device can be found on eBay for about \$4 and it will measure the distance to a target from 3cm to 3m. It works by sending an ultrasonic sound pulse and measuring the time it takes for the echo to be returned.

Compatible sensors are the SRF05, SRF06, Parallax PING and the DYP-ME007 (which is waterproof and therefore good for monitoring the level of a water tank).

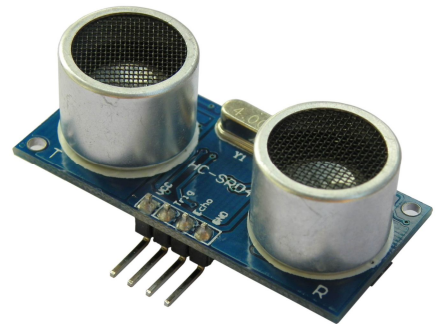
In previous versions of the Micromite firmware this function was built into MMBasic but now it is distributed as a CFunction module which works the same. See the file *Distance.pdf* which is included in the *Embedded C Modules* folder in the Micromite firmware zip file.

On the Micromite you use the DISTANCE function as follows:

```
d = DISTANCE(trig, echo)
```

Where trig is the I/O pin connected to the "trig" input of the sensor and echo is the pin connected the "echo" output of the sensor. You can also use 3-pin devices and in that case only one pin number is specified.

The value returned is the distance in centimetres to the target. The I/O pins are automatically configured by this function but note that they should be 5V capable as the HC-SR04 is a 5V device.



LCD Display

The LCD command will display text on a standard LCD module with the minimum of programming effort.

This command will work with LCD modules that use the KS0066, HD44780 or SPLC780 controller chip and have 1, 2 or 4 lines. Typical displays include the LCD16X2 (futurlec.com), the Z7001 (altronics.com.au) and the QP5512 (jaycar.com.au). eBay is another good source where prices can range from \$10 to \$50.

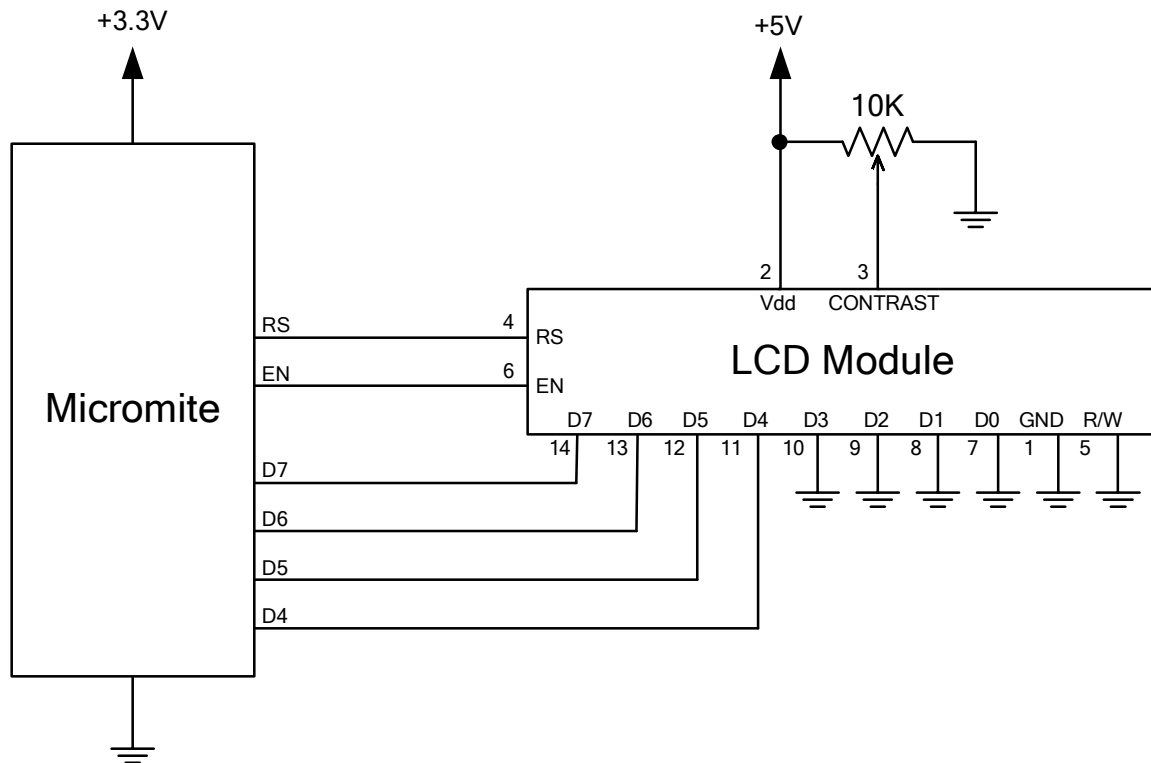
To setup the display you use the LCD INIT command:

```
LCD INIT d4, d5, d6, d7, rs, en
```

d4, d5, d6 and d7 are the numbers of the I/O pins that connect to inputs D4, D5, D6 and D7 on the LCD module (inputs D0 to D3 and R/W on the module should be connected to ground). 'rs' is the pin connected to the register select input on the module (sometimes called CMD or DAT). 'en' is the pin connected to the enable or chip select input on the module.



Any I/O pins on the Micromite can be used and you do not have to set them up beforehand (the LCD command automatically does that for you). The following shows a typical set up.



To display characters on the module you use the LCD command:

```
LCD line, pos, data$
```

Where line is the line on the display (1 to 4) and pos is the position on the line where the data is to be written (the first position on the line is 1). data\$ is a string containing the data to write to the LCD display. The characters in data\$ will overwrite whatever was on that part of the LCD.

The following shows a typical usage where d4 to d7 are connected to pins 2 to 4 on the Micromite, rs is connected to pin 23 and en to pin 24..

```
LCD INIT 2, 3, 4, 5, 23, 24
LCD 1, 2, "Temperature"
LCD 2, 6, STR$(TEMPR(15))      ' DS18B20 connected to pin 15
```

Note that this example also uses the TEMPR() function to get the temperature (described above).

Keypad Interface

A keypad is a low tech method of entering data into a Micromite based system. The Micromite supports either a 4x3 keypad or a 4x4 keypad and the monitoring and decoding of key presses is done in the background. When a key press is detected an interrupt will be issued where the program can deal with it.

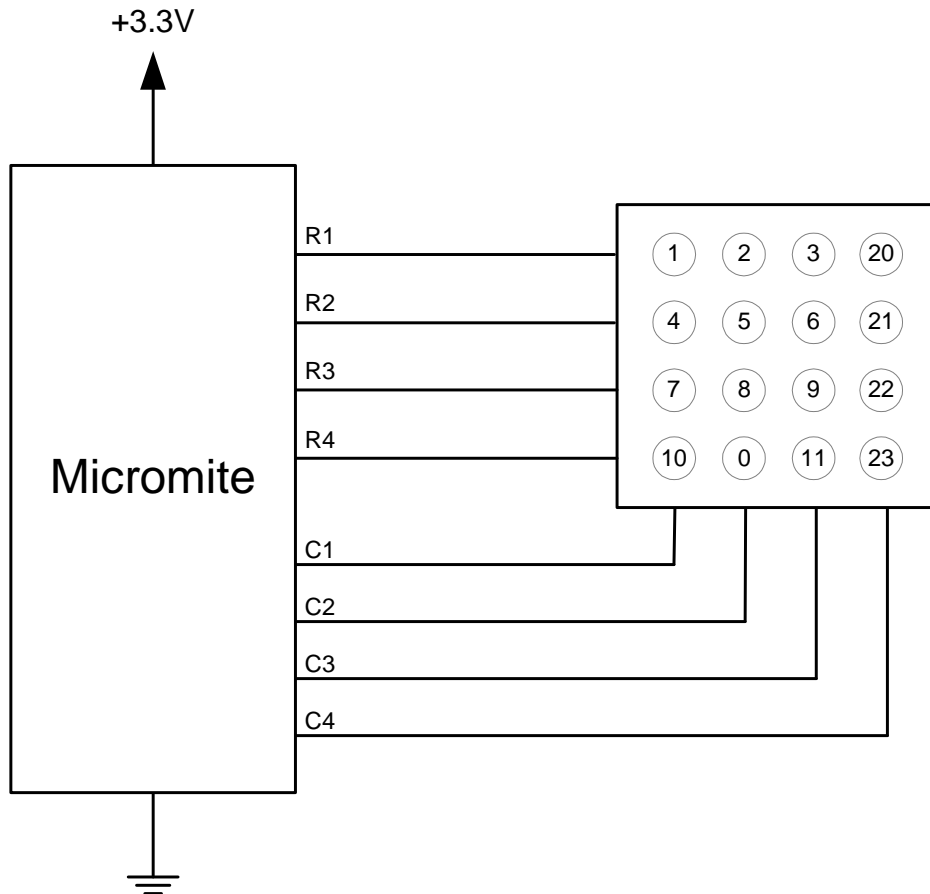
Examples of a 4x3 keypad and a 4x4 keypad are the Altronics S5381 and S5383 (go to www.altronics.com).

To enable the keypad feature you use the command:

```
KEYPAD var, int, r1, r2, r3, r4, c1, c2, c3, c4
```

Where var is a variable that will be updated with the key code and int is the name of the interrupt subroutine to call when a new key press has been detected. r1, r2, r3 and r4 are the pin numbers used for the four row connections to the keypad (see the diagram below) and c1, c2, c3 and c4 are the column connections. c4 is only used with 4x4 keypads and should be omitted if you are using a 4x3 keypad.

Any I/O pins on the Micromite can be used and you do not have to set them up beforehand, the KEYPAD command will automatically do that for you.



The detection and decoding of key presses is done in the background and the program will continue after this command without interruption. When a key press is detected the value of the variable var will be set to the number representing the key (this is the number inside the circles in the diagram above). Then the interrupt will be called.

For example:

```

Keypad KeyCode, KP_Int, 2, 3, 4, 5, 21, 22, 23    ' 4x3 keyboard
DO
  < body of the program >
LOOP

SUB KP_Int                                         ' a key press has been detected
  PRINT "Key press = " KeyCode
END SUB

```

Switch Inputs

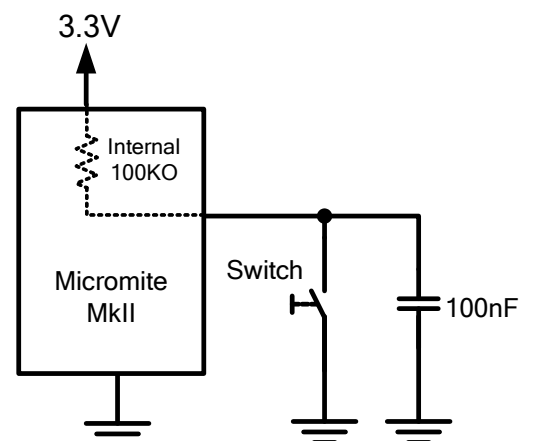
Often there is a need to use a switch as an input to a Micromite based project. This is easy to implement as a Micromite input can be specified with an internal pullup resistor. This resistor is internal to the Micromite and (when specified) will be connect between the input pin and the 3.3V supply (it is about 100K).

This means that the switch can be connected between the ground and the input pin. When the switch is open the input will be high (pulled up by the internal resistor) and when closed the input will be zero.

To specify a pullup resistor you use SETPIN as follows:

```
SETPIN pin, DIN, PULLUP
```

When you use a switch you will also have to consider the issue of contact bounce. This is when the switch contacts mechanically touch and then bounce apart momentarily due to the momentum of the



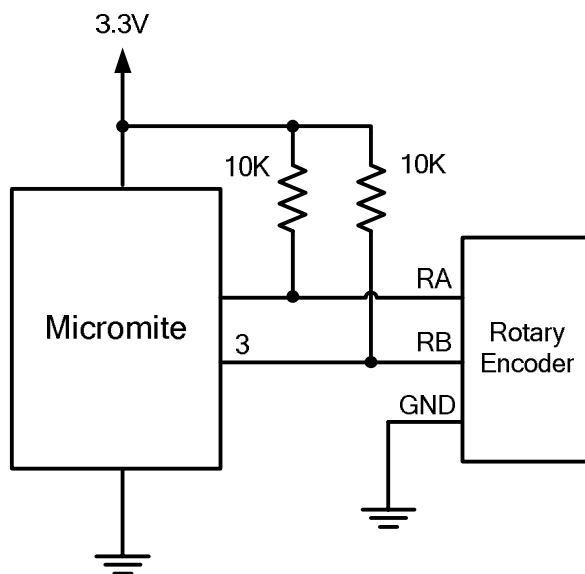
mechanical assembly. Because the Micromite runs very fast a BASIC program could see this as a secession of quick button presses rather than a single press.

You could check for this in your program, for example by checking 100ms after the first contact closure to confirm that the contacts are indeed closed. A simpler solution is to connect a 100nF capacitor across the switch contacts as illustrated above. This capacitor in association with the internal pullup resistor will average out any rapid contact bounce so that the program will see a smooth transition from on to off and vice versa.

Rotary Encoders

A rotary encoder is a handy method of adjusting the value of parameters in a microcontroller project. A typical encoder can be mounted on a panel with a knob and looks like a potentiometer. As the knob is turned it generates a series of signals known as a Gray Code. The program fragment below shows how to decode this code to update a variable in the Micromite.

A standard encoder has two outputs (labelled RA and RB) and a common ground. The outputs should be wired with pullup resistors as shown below:



And this program fragment can be used to decode the output:

```
SETPIN 3, DIN           ' setup RB as an input
SETPIN 2, INTH, RInt    ' setup an interrupt when RA goes high

DO
  < main body of the program >
LOOP

SUB RInt                ' Interrupt to decode the encoder output
  IF PIN(3) = 1 then
    Value = Value + 1    ' clockwise rotation
  ELSE
    Value = Value - 1    ' anti clockwise rotation
  ENDIF
END SUB
```

This program assumes that the encoder is connected to I/O pins 2 and 3 on the Micromite, however any pins can be used by changing the pin numbers in the program. "Value" is the variable whose value will be updated as the shaft of the encoder is rotated.

Note that this program is intended for simple user input where a skipped or duplicated step is not considered important. It is not suitable for high speed or precision input.

Program courtesy MicroBlocks on the Back Shed Forum.

Controlling a Servo

Servos are a motor with integrated gears and a control system that allows the position of the shaft to be precisely controlled. The Micromite can simultaneously control up to five servos.

Standard servos allow the shaft to be positioned at various angles, usually between -90 and +90 degrees. Continuous rotation servos allow the rotation of the shaft to be set to various speeds.

The position of the servo is controlled by a pulse which is repeated every 20ms. Generally a pulse width of 0.8ms will position the rotor at -90°, a pulse width of 2.2ms will position it at +90° and 1.5ms will centre the rotor. These numbers can vary considerably between manufacturers.

Depending on their size servos can be quite powerful and provide a convenient way for the Micromite to control the mechanical world.

Most servos require a high current 5V power source and have two power leads, red for +V and black for ground. The third wire is the control signal which should be connected to a Micromite SERVO I/O pin.

The Micromite has two servo controllers with the first being able to control up to three servos and the second two servos. To drive the servo you use this command for the servos connected to controller 1:

```
SERVO 1, 1A, 1B, 1C
```

And this for servos connected to controller 2:

```
SERVO 2, 2A, 2B
```

Where 1A, 1B, 2A, etc are the desired pulse widths in milliseconds for each output of the channel. The output pins are listed on pages 6 and 7 where the outputs are designated as PWM 1A, PWM 1B, PWM 2A, etc (the PWM and SERVO commands are closely related and use the same I/O pins). If you want to control less than this number of servos you can leave the unused output off the list and use that pin as a general purpose I/O.

The pulse width can be specified with a high resolution (about 0.005 ms). For example, the following will position the rotor of the servo connected to channel 1A to near its centre:

```
SERVO 1, 1.525
```

Following the SERVO command the Micromite will generate a continuous stream of pulses in the background until another servo command is given or the STOP option is used (which will terminate the output).

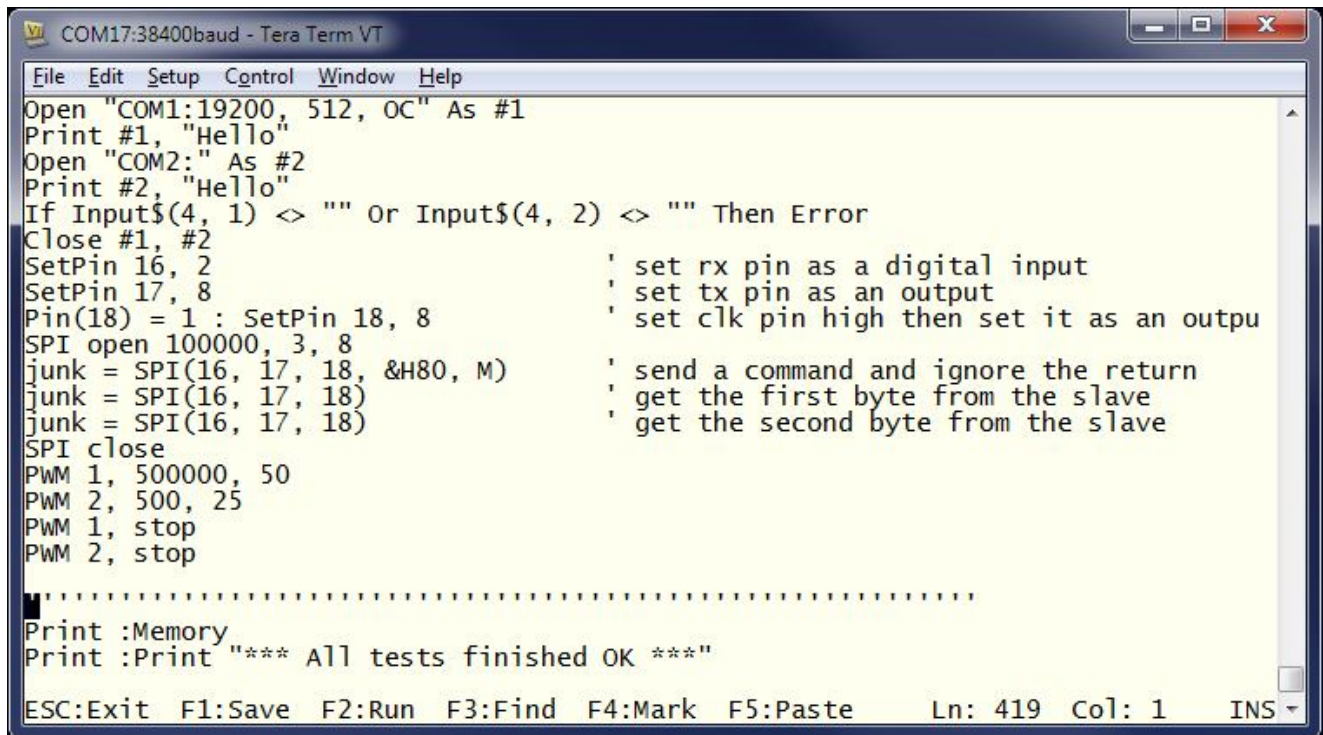
As another example, the following will swing two servos back and forth alternatively every 5 seconds: These servos should be connected to the outputs PWM 1A and PWM 1B.

```
DO
  SERVO 1, 0.8, 2.2
  PAUSE 5000
  SERVO 1, 2.2, 0.8
  PAUSE 5000
LOOP
```



Full Screen Editor

An important productivity feature of the Micromite is the full screen editor. This will work with any VT100 compatible terminal emulator (Tera Term is recommended).



```
COM17:38400baud - Tera Term VT
File Edit Setup Control Window Help
Open "COM1:19200, 512, OC" As #1
Print #1, "Hello"
Open "COM2:" As #2
Print #2, "Hello"
If Input$(4, 1) <> "" Or Input$(4, 2) <> "" Then Error
Close #1, #2
SetPin 16, 2           ' set rx pin as a digital input
SetPin 17, 8           ' set tx pin as an output
Pin(18) = 1 : SetPin 18, 8 ' set clk pin high then set it as an output
SPI open 100000, 3, 8
junk = SPI(16, 17, 18, &H80, M) ' send a command and ignore the return
junk = SPI(16, 17, 18)          ' get the first byte from the slave
junk = SPI(16, 17, 18)          ' get the second byte from the slave
SPI close
PWM 1, 500000, 50
PWM 2, 500, 25
PWM 1, stop
PWM 2, stop
.....
Print :Memory
Print :Print "*** All tests finished OK ***"
ESC:Exit F1:Save F2:Run F3:Find F4:Mark F5:Paste Ln: 419 Col: 1 INS
```

The full screen program editor is invoked with the EDIT command. The cursor will be automatically positioned at the last place that you were editing at or, if your program had just been stopped by an error, the cursor will be positioned at the line that caused the error.

If you are used to an editor like Notepad you will find that the operation of this editor is familiar. The arrow keys will move your cursor around in the text, home and end will take you to the beginning or end of the line. Page up and page down will do what their titles suggest. The delete key will delete the character at the cursor and backspace will delete the character before the cursor. The insert key will toggle between insert and overtype modes.

About the only unusual key combination is that two home key presses will take you to the start of the program and two end key presses will take you to the end.

At the bottom of the screen the status line will list the various function keys used by the editor and their action. In more details these are:

- | | |
|-----------|---|
| ESC | This will cause the editor to abandon all changes and return to the command prompt with the program memory unchanged. If you have changed the text you will be asked if you really what want to abandon your changes. |
| F1: SAVE | This will save the program to program memory and return to the command prompt. |
| F2: RUN | This will save the program to program memory and immediately run it. |
| F3: FIND | This will prompt for the text that you want to search for. When you press enter the cursor will be placed at the start of the first entry found. |
| SHIFT-F3 | Once you have used the search function you can repeatedly search for the same text by pressing SHIFT-F3. |
| F4: MARK | This is described in detail below. |
| F5: PASTE | This will insert (at the current cursor position) the text that had been previously cut or copied (see below). |

If you pressed the mark key (F4) the editor will change to the *mark mode*. In this mode you can use the arrow keys to mark a section of text which will be highlighted in reverse video. You can then delete, cut or copy the marked text. In this mode the status line will change to show the functions of the function keys in the mark mode. These keys are:

ESC	Will exit mark mode without changing anything.
F4: CUT	Will copy the marked text to the clipboard and remove it from the program.
F5: COPY	Will just copy the marked text to the clipboard.
DELETE	Will delete the marked text leaving the clipboard unchanged.

You can also use control keys instead of the functions keys listed above. These control keystrokes are:

LEFT	Ctrl-S	RIGHT	Ctrl-D	UP	Ctrl-E	DOWN	Ctrl-X
HOME	Ctrl-U	END	Ctrl-K	PageUp	Ctrl-P	PageDn	Ctrl-L
DEL	Ctrl-]	INSERT	Ctrl-N	F1	Ctrl-Q	F2	Ctrl-W
F3	Ctrl-R	ShiftF3	Ctrl-G	F4	Ctrl-T	F5	Ctrl-Y

The best way to learn the full screen editor is to simply fire it up and experiment.

The editor is a very productive method of writing a program. With the command EDIT you can write your program on the Micromite. Then, by pressing the F2 key, you can save and run the program. If your program stops with an error you can press the function key F4 which will run the command EDIT and place you back in the editor with the cursor positioned at the line that caused the error. This edit/run/edit cycle is very fast.

Using the OPTION BAUDRATE command the baud rate of the console can be changed to any speed up to 230400 bps. Changing the console baud rate to a higher speed makes the full screen editor much faster in redrawing the screen. If you have a reliable connection to the Micromite it is worth changing the speed to at least 115200.

The editor expects that the terminal emulator is set to 24 lines per screen with each line 80 characters wide. Both of these assumptions can be changed with the OPTION DISPLAY command to suit non standard displays.

Note that a terminal emulator can lose its position in the text with multiple fast keystrokes (like the up and down arrows). If this happens you can press the HOME key twice which will force the editor to jump to the start of the program and redraw the display.

Colour Coded Editor Display

The editor has the ability to colour code the edited program with keywords, numbers and comments displayed in different colours. By default the output is not colour coded but this feature can be enabled with the command:

```
OPTION COLOURCODE ON
```

or disabled with:

```
OPTION COLOURCODE OFF
```

This setting is saved in flash memory and is automatically applied on startup.

Note:

- This feature requires a terminal emulator that can interpret the appropriate escape codes and respond correctly. It works correctly with Tera Term however Putty needs its default background colour to be changed to white (Settings >> Colours >> Default Background >> Modify).
- Colour coding the editor's output requires many extra characters to be sent to the terminal emulator and this can slow down the screen update at 38400 baud. If colour coding is used it is recommended that the baud rate be set to a higher speed as discussed above.

Defining and Using Variables

Variables are a way for a program to store numbers or text, MMBasic on the Micromite supports three different types of variables:

1. Floating point.

These can store a number with a decimal point and fraction (eg, 45.386) and also very large numbers. However, they will lose accuracy when more than six or seven significant digits are stored or manipulated. Floating point variables are specified by adding the suffix '!' to a variable's name (eg, i!, nbr!, etc). They are also the default when a variable is created without a suffix (eg, i, nbr, etc).

2. 64-bit signed integer.

These can store positive or negative numbers with up to 19 decimal digits without losing accuracy but they cannot store fractions (ie, the part following the decimal point). These are specified by adding the suffix '%' to a variable's name. For example, i%, nbr%, etc. Note that during arithmetic operations (particularly addition and multiplication) no check is made for an overflow which may result in the final value requiring more than the number of digits supported. In that case the result will be nonsense.

3. A String.

A string will store a sequence of characters (eg, "Tom"). Each character in the string is stored as an eight bit number and can therefore have a decimal value of 0 to 255. String variable names are terminated with a '\$' symbol (eg, name\$, s\$, etc). Strings can be up to 255 characters long.

Note that it is illegal to use the same variable name with different types. Eg, using `nbr!` and `nbr%` in the same program would cause an error.

Most programs use floating point variables as these can deal with the numbers used in typical situations and are more intuitive when dealing with division and fractions. So, if you are not bothered with the details, always use floating point.

When a constant number is used it will be assumed that it is an integer if a decimal point or exponent is not used. For example, 1234 will be interpreted as an integer and 1234.0 will be interpreted as a floating point number. String constants are always surrounded by double quote marks (eg, "text string").

OPTION DEFAULT

A variable can be used without a suffix (ie, !, % or \$) and in that case MMBasic will use the default type of floating point. For example, the following will create a floating point variable:

```
Nbr = 1234
```

However the default can be changed with the **OPTION DEFAULT** command. For example, **OPTION DEFAULT INTEGER** will specify that all variables without a specific type will be integer. So, the following will create an integer variable:

```
OPTION DEFAULT INTEGER
Nbr = 1234
```

The default can be set to **FLOAT** (which is the default when a program is run), **INTEGER**, **STRING** or **NONE**. In the latter case all variables must be specifically typed otherwise an error will occur.

The **OPTION DEFAULT** command can be placed anywhere in the program and changed at any time but good practice dictates that if it is used it should be placed at the start of the program and left unchanged.

OPTION EXPLICIT

By default MMBasic will automatically create a variable when it is first referenced. So, `Nbr = 1234` will create the variable and set it to the number 1234 at the same time. This is convenient for short and quick programs but it can lead to subtle and difficult to find bugs in large programs. For example, in the third line of this fragment the variable `Nbr` has been misspelt as `Nr`. As a consequence the variable `Nr` would be created with a value of zero and the value of `Total` would be wrong.

```
Nbr = 1234
Incr = 2
Total = Nr + Incr
```

The **OPTION EXPLICIT** command tells MMBasic to not automatically create variables. Instead they must be explicitly defined using the **DIM** or **LOCAL** commands (see below) before they are used.

If the **OPTION EXPLICIT** command was used as shown below the error would become obvious when the program was run:

```
> LIST
OPTION EXPLICIT
DIM Nbr, Incr, Total
Nbr = 1234
Incr = 2
Total = Nr + Incr
>
> RUN
[5] Total = Nr + Incr
Error: NR is not declared
>
```

The use of **OPTION EXPLICIT** is recommended to support good programming practice. If it is used it should be placed at the start of the program before any variables are used.

DIM and LOCAL

The **DIM** and **LOCAL** commands can be used to define a variable and set its type and are mandatory when the **OPTION EXPLICIT** command is used.

The **DIM** command will create a global variable that can be seen and used throughout the program including inside subroutines and functions. However, if you require the definition to be visible only within the subroutine or function, you should use the **LOCAL** command. **LOCAL** has exactly the same syntax as **DIM**.

If **LOCAL** is used to specify a variable with the same name as a global variable then the global variable will be hidden to the subroutine or function and any references to the variable will only refer to the variable defined by the **LOCAL** command. Any variable created by **LOCAL** will vanish when the program leaves the subroutine.

At its simplest level **DIM** and **LOCAL** can be used to define one or more variables based on their type suffix or the **OPTION DEFAULT** in force at the time. For example:

```
DIM nbr%, s$
```

But it can also be used to define one or more variables with a specific type when the type suffix is not used:

```
DIM INTEGER nbr, nbr2, nbr3, etc
```

In this case **nbr**, **nbr2**, **nbr3**, etc are all created as integers. When you use the variable within a program you do not need to specify the type suffix. For example, **MyStr** in the following works perfectly as a string variable:

```
DIM STRING MyStr
MyStr = "Hello"
```

The **DIM** and **LOCAL** commands will also accept the Microsoft practice of specifying the variable's type after the variable with the keyword **"AS"**. For example:

```
DIM nbr AS INTEGER, s AS STRING
```

In this case the type of each variable is set individually (not as a group as when the type is placed before the list of variables).

The variables can also be initialised while being defined. For example:

```
DIM INTEGER a = 5, b = 4, c = 3
DIM s$ = "World", i% = &FHHHHHHH
DIM msg AS STRING = "Hello" + " " + s$
```

The value used to initialise the variable can be an expression including user defined functions.

The **DIM** or **LOCAL** commands are also used to define an array and all the rules listed above apply when defining an array. For example, you can use:

```
DIM INTEGER nbr(10), nbr2, nbr3(5,8), etc
```

When initialising an array the values are listed as comma separated values with the whole list surrounded by brackets. For example:

```
DIM INTEGER nbr(5) = (12, 13, 14, 15, 16)
```

or

```
DIM days(7) AS STRING = ("","Sun","Mon","Tue","Wed","Thu","Fri","Sat")
```

STATIC

Inside a subroutine or function it is sometimes useful to create a variable which is only visible within the subroutine or function (like a `LOCAL` variable) but retains its value between calls to the subroutine or function. You can do this by using the `STATIC` command. `STATIC` can only be used inside a subroutine or function and uses the same syntax as `LOCAL` and `DIM`. The difference is that its value will be retained between calls to the subroutine or function (ie, it will not be initialised on the second and subsequent calls).

For example, if you had the following subroutine and repeatedly called it, the first call would print 5, the second 6, the third 7 and so on.

```
SUB Foo
    STATIC var = 5
    PRINT var
    var = var + 1
END SUB
```

Note that the initialisation of the static variable to 5 (as in the above example) will only take effect on the first call to the subroutine. On subsequent calls the initialisation will be ignored as the variable had already been created on the first call.

As with `DIM` and `LOCAL` the variables created with `STATIC` can be float, integers or strings and arrays of these with or without initialisation.

CONST

Often it is useful to define an identifier that represents a value without the risk of the value being accidentally changed - which can happen if variables were used for this purpose (this practice encourages another class of difficult to find bugs).

Using the `CONST` command you can create an identifier that acts like a variable but is set to a value that cannot be changed. For example:

```
CONST InputVoltagePin = 26
CONST MaxValue = 2.4
```

The identifiers can then be used in a program where they make more sense to the casual reader than simple numbers. For example:

```
IF PIN(InputVoltagePin) > MaxValue THEN SoundAlarm
```

A number of constants can be created on the one line:

```
CONST InputVoltagePin = 26, MaxValue = 2.4, MinValue = 1.5
```

The value used to initialise the constant is evaluated when the constant is created and can be an expression including user defined functions.

The type of the constant is derived from the value assigned to it; so for example, `MaxValue` above will be a floating point constant because 2.4 is a floating point number. The type of a constant can also be explicitly set by using a type suffix (ie, `!`, `%` or `$`).

Mixing Floating Point and Integers

MMBasic automatically handles conversion of numbers between floating point and integers. If an operation mixes both floating point and integers (eg, `PRINT A% + B!`) the integer will be converted to a floating point number first, then the operation performed and a floating point number returned. If both sides of the operator are integers then an integer operation will be performed and an integer returned.

The one exception is the normal division ("`/`") which will always convert both sides of the expression to a floating point number and then return a floating point number. For integer division you should use the integer division operator "`\`".

Functions will return a float or integer depending on their characteristics. For example, `PIN()` will return an integer when the pin is configured as a digital input but a float when configured as an analog input.

If necessary you can convert a float to an integer with the `INT()` function. It is not necessary to specifically convert an integer to a float but if it was needed the integer value could be assigned to a floating point variable and it will be automatically converted in the assignment.

64-bit Unsigned Integers

The Micromite supports 64-bit signed integers. This means that there are 63 bits for holding the number and one bit (the most significant bit) which is used to indicate the sign (positive or negative). However it is possible to use full 64-bit unsigned numbers as long as you do not do any arithmetic on the numbers.

64-bit unsigned numbers can be created using the &H, &O or &B prefixes to a number and these numbers can be stored in an integer variable. You then have a limited range of operations that you can perform on these numbers. They are << (shift left), >> (shift right), AND (bitwise and), OR (bitwise or), XOR (bitwise exclusive or), = (equal to) and <> (not equal to). Arithmetic operators such as +, -, etc may be confused by a 64-bit unsigned number and could return nonsense results.

To display 64-bit unsigned numbers you should use the HEX\$(), OCT\$() or BIN\$() functions.

For example, the following 64-bit unsigned operation will return the expected results:

```
X% = &HFFFF0000FFFF0044
Y% = &H800FFFFFFFFFFFFFFF
X% = X% AND Y%
PRINT HEX$(X%, 16)
```

Will display "800F0000FFFF0044"

Using the I/O pins

Digital Inputs

A digital input is the simplest type of input configuration. If the input voltage is higher than 2.5V the logic level will be true (numeric value of 1) and anything below 0.65V will be false (numeric value of 0). The inputs use a Schmitt trigger input so anything in between these levels will retain the previous logic level. Pins marked as 5V are 5V tolerant and can be directly connected to a circuit that generates up to 5.5V without the need for voltage dropping resistors.

In your BASIC program you would set the input as a digital input and use the PIN() function to get its level. For example:

```
SETPIN 23, DIN
IF PIN(23) = 1 THEN PRINT "High"
```

The SETPIN command configures pin 23 as a digital input and the PIN() function will return the value of that pin (the number 1 if the pin is high). The IF command will then execute the command after the THEN statement if the input was high. If the input pin was low the program would just continue with the next line in the program.

The SETPIN command also recognises a couple of options that will connect an internal resistor from the input to either the supply or ground. This is called a "pullup" or "pulldown" resistor and is handy when connecting to a switch as it saves having to install an external resistor to place a voltage across the contacts.

Analog Inputs

Pins marked as ANALOG can be configured to measure the voltage on the pin. The input range is from zero to 3.3V and the PIN() function will return the voltage. For example:

```
> SETPIN 23, AIN
> PRINT PIN(23)
2.345
>
```

You will need a voltage divider if you want to measure voltages greater than 3.3V. For small voltages you may need an amplifier to bring the input voltage into a reasonable range for measurement.

The measurement uses the analog power pin (pin 28 on the 28-pin chip and 17 on the 44-pin chip) as the reference voltage and MMBasic scales the reading by assuming that the voltage on this pin is exactly 3.3V. Normally the Micromite is powered from a voltage regulator so this assumption is correct. However, when battery power is used, the supply voltage can vary which will cause inaccurate readings. In that case the program should scale the reading accordingly. For example:

$$A = (\text{PIN}(x) / 3.3) * \text{PowerV}$$

where "PowerV" is the voltage on the analog power pin.

The measurement of voltage is very sensitive to noise on the Analog Power and Ground pins. For accurate and repeatable voltage measurements care should be taken with the PCB design to isolate the analog circuit from the digital circuits and ensure that the Analog Power supply is as noise free as possible.

Counting Inputs

The pins marked as COUNT can be configured as counting inputs to measure frequency, period or just count pulses on the input.

For example, the following will print the frequency of the signal on pin 15:

```
> SETPIN 15, FIN
> PRINT PIN(15)
110374
>
```

In this case the frequency is 110.374 kHz.

By default the gate time is one second which is the length of time that MMBasic will use to count the number of cycles on the input and this means that the reading is updated once a second with a resolution of 1 Hz. By specifying a third argument to the SETPIN command it is possible to specify an alternative gate time between 10ms and 100000ms. Shorter times will result in the readings being updated more frequently but the value returned will have a lower resolution. The PIN() function will always return the frequency in Hz regardless of the gate time used.

For example, the following will set the gate time to 10ms with a corresponding loss of resolution:

```
> SETPIN 15, FIN, 10
> PRINT PIN(15)
110300
>
```

For accurate measurement of signals less than 10 Hz it is generally better to measure the period of the signal. When set to this mode the Micromite will measure the number of milliseconds between sequential rising edges of the input signal. The value is updated on the low to high transition so if your signal has a period of (say) 100 seconds you should be prepared to wait that amount of time before the PIN() function will return an updated value.

The COUNTING pins can also count the number of pulses on their input. When a pin is configured as a counter (for example, SETPIN 15, CIN) the counter will be reset to zero and Micromite will then count every transition from a low to high voltage. The counter can be reset to zero again by executing the SETPIN command a second time (even though the input was already configured as a counter).

The response to input pulses is very fast and the Micromite can count pulses as narrow as 10 nS. The frequency response depends on the load on the processor (ie, the number of counting inputs and if serial or I²C communications is used). It can be as high as 800 kHz with no other activity but is normally about 300 kHz.

Digital Outputs

All I/O pins can be configured as a standard digital output. This means that when an output pin is set to logic low it will pull its output to zero and when set high it will pull its output to 3.3V. In MMBasic this is done with the PIN command. For example PIN(15) = 0 will set pin 15 to low while PIN(15) = 1 will set it high. When operating in this mode, a pin is capable of sourcing 10 mA which is sufficient to drive a LED or other logic circuits running at 3.3V.

The "OC" option on the SETPIN command makes the output pin open collector. This means that the output driver will pull the output low (to zero volts) when the output is set to a logic low but will go to a high impedance state when set to logic high. If you then connect a pull-up resistor to 5V (on pins that are 5V tolerant) the logic high level will be 5V (instead of 3.3V using the standard output mode). The maximum pull-up voltage in this mode is 5.5V.

Pulse Width Modulation

The PWM (Pulse Width Modulation) command allows the Micromite to generate square waves with a program controlled duty cycle. By varying the duty cycle you can generate a program controlled voltage output for use in controlling external devices that require an analog input (power supplies, motor controllers, etc). The PWM outputs are also useful for driving servos and for generating a sound output via a small transducer.

There are two PWM controllers; the first has three outputs and the second two to give a total of five PWM outputs. The frequency of each controller can be independently set from 20 Hz to 500 kHz and the duty cycle for each output (ie, five outputs) can also be independently set from between 0% and 100% with a 0.1% resolution when the frequency is below 25 kHz (above 25 kHz the resolution is 1% or better up to 250 kHz).

When the Micromite is powered up or the PWM OFF command is used the PWM outputs will be set to high impedance (they are neither off nor on). So, if you want the PWM output to be low by default (zero power in most applications) you should use a resistor to pull the output to ground when it is set to high impedance. Similarly, if you want the default to be high (full power) you should connect the resistor to 3.3V.

Interrupts

Interrupts are a handy way of dealing with an event that can occur at an unpredictable time. An example is when the user presses a button. In your program you could insert code after each statement to check to see if the button has been pressed but an interrupt makes for a cleaner and more readable program.

When an interrupt occurs MMBasic will execute a special section of code and when finished return to the main program. The main program is completely unaware of the interrupt and will carry on as normal.

Any I/O pin that can be used as a digital input can be configured to generate an interrupt using the SETPIN command with up to ten interrupts active at any one time. Interrupts can be set up to occur on a rising or falling digital input signal (or both) and will cause an immediate branch to the specified user defined subroutine. The target can be the same or different for each interrupt. Return from an interrupt is via the END SUB or EXIT SUB commands. Note that no parameters can be passed to the subroutine however within the interrupt subroutine calls to other subroutines are allowed.

If two or more interrupts occur at the same time they will be processed in order of the interrupts as defined with SETPIN. During the processing of an interrupt all other interrupts are disabled until the interrupt subroutine returns. During an interrupt (and at all times) the value of the interrupt pin can be accessed using the PIN() function.

Interrupts can occur at any time but they are disabled during INPUT statements. Also interrupts are not recognised during some long hardware related operations (eg, the TEMPR() function) although they will be recognised if they are still present when the operation has finished.. When using interrupts the main program is completely unaffected by the interrupt activity unless a variable used by the main program is changed during the interrupt.

Because interrupts run in the background they can cause difficult to diagnose bugs. Keep in mind the following factors when using interrupts:

- For most programs MMBasic will respond to an interrupt in under 30µs however some commands (such as the TEMPR() function) can block interrupts for up to 200ms and it is possible for an interrupt (eg, a button press) to occur and vanish within this window and in that case it will never be recognised.
- When inside an interrupt all other interrupts are blocked so your interrupts should be short and exit as soon as possible. For example, never use PAUSE inside an interrupt. If you have some lengthy processing to do you should simply set a flag and immediately exit the interrupt, then your main program loop can detect the flag and do whatever is required.
- The subroutine that the interrupt calls (and any other subroutines called by it) should always be exclusive to the interrupt. If you must call a subroutine that is also used by an interrupt you must disable the interrupt first (you can reinstate it after you have finished with the subroutine).
- Remember to disable an interrupt when you have finished needing it – background interrupts can cause strange and non-intuitive bugs.

In addition to interrupts generated by the change in state of an I/O pin, an interrupt can also be generated by other sections of MMBasic including timers and communications ports. The list of all these interrupts (in high to low priority ranking) is:

1. CFunction Interrupt
2. ON KEY
3. I2C Slave Rx
4. I2C Slave Tx
5. COM1: Serial Port
6. COM2: Serial Port
7. COM3: Serial Port (MM+ only)
8. COM4: Serial Port (MM+ only)
9. GUI Int Down (MM+ only)
10. GUI Int Up (MM+ only)
11. WAV Finished (MM+ only)
12. IR Receive
13. I/O Pin Interrupts in order of definition
14. Tick Interrupts (1 to 4 in that order)

As an example: If an ON KEY interrupt occurred at the same time as a COM1: interrupt the ON KEY interrupt subroutine would be executed first and then, when the interrupt subroutine finished, the COM1: interrupt subroutine would then be executed.

Timing

MMBasic has a number of features that make it easy to time events and control external circuitry that needs timing.

MMBasic maintains an internal clock. You can get the current date and time using the DATE\$ and TIME\$ functions and you can set them by assigning the new date and time to them. The calendar will start from zero when the Micromite is first powered up but by using the I²C feature you can easily get the time from a real time clock chip like the PCF8563.

The PAUSE command will freeze the execution of the program for a specified number of milliseconds. So, to create a 12ms wide pulse you could use the following:

```
SETPIN 4, DOUT
PIN(4) = 1
PAUSE 12
PIN(4) = 0
```

You can also create a pulse using the PULSE command. This will generate very narrow pulses (eg, 20µs) or long pulses up to several days. Long pulses are run in the background and the program will continue uninterrupted.

Another useful feature is the TIMER function which acts like a stopwatch. You can set it to any value (usually zero) and it will count upwards every millisecond.

A timing function is also provided by the SETTICK command. This command will generate an interrupt at regular intervals (specified in milliseconds). Think of it as the regular "tick" of a watch. For example, the following code fragment will print the current time and the voltage on pin 2 every second. This process will run independently of the main program which could be doing something completely unrelated.

```
SETPIN 2, AIN
SETTICK 1000, DOINT
DO
    \ main processing loop
LOOP

SUB DOINT          \ tick interrupt
    PRINT TIME$, PIN(2)
END SUB
```

The second line sets up the "tick" interrupt, the first parameter of SETTICK is the period of the interrupt (1000ms) and the second is the starting label of the interrupt code. Every second (ie, 1000 ms) the main processing loop will be interrupted and the program starting at the label DOINT will be executed.

Up to four "tick" interrupts can be setup. These interrupts have the lowest priority.

The accuracy of the Micromite's internal clock can vary by a little due to manufacturing tolerances and temperature. To compensate for this the OPTION CLOCKTRIM command can be used to trim the clock to a more accurate value.

Defined Subroutines and Functions

Defined subroutines and functions are useful features to help in organising programs so that they are easy to modify and read. A defined subroutine or function is simply a block of programming code that is contained within a module and can be called from anywhere within your program. It is the same as if you have added your own command or function to the language.

For example, assume that you would like to have the command FLASH added to MMBasic, its job would be to flash a LED on pin 2. You could define a subroutine like this:

```
SUB FLASH
  SETPIN 2, DOUT
  PIN(2) = 1
  PAUSE 100
  PIN(2) = 0
END SUB
```

Then, in your program you just use the command FLASH to flash the LED. For example:

```
IF A <= B THEN FLASH
```

If the FLASH subroutine was in program memory you could even try it out at the command prompt, just like any command in MMBasic. The definition of the FLASH subroutine can be anywhere in the program but typically it is at the start or end. If MMBasic runs into the definition while running your program it will simply skip over it.

Subroutine Arguments

Defined subroutines can have arguments (sometimes called parameter lists). In the definition of the subroutine they look like this:

```
SUB MYSUB (arg1, arg2$, arg3)
  <statements>
  <statements>
END SUB
```

And when you call the subroutine you can assign values to the arguments. For example:

```
MYSUB 23, "Cat", 55
```

Inside the subroutine `arg1` will have the value 23, `arg2$` the value of "Cat", and so on. The arguments act like ordinary variables but they exist only within the subroutine and will vanish when the subroutine ends. You can have variables with the same name in the main program and they will be different from arguments defined for the subroutine (at the risk of making debugging harder).

When calling a subroutine you can supply less than the required number of values. For example:

```
MYSUB 23
```

In that case the missing values will be assumed to be either zero or an empty string. For example, in the above case `arg2$` will be set to "" and `arg3` will be set to zero. This allows you to have optional values and, if the value is not supplied by the caller, you can take some special action.

You can also leave out a value in the middle of the list and the same will happen. For example:

```
MYSUB 23, , 55
```

Will result in `arg2$` being set to "".

Rather than using the type suffix (eg, the \$ in `arg2$`) you can use the suffix `AS <type>` in the definition of the subroutine argument and then the argument will be known as the specified type, even when the suffix is not used. For example:

```
SUB MYSUB (arg1, arg2 AS STRING, arg3)
  IF arg2 = "Cat" THEN ...
END SUB
```

If you do not define the type of the argument it will default to float or that set by `OPTION DFAULT`. Further, if you used `OPTION DEFAULT NONE` to force you to define the type of all variables you will also have to define them in the subroutine or function definition.

Local Variables

Inside a subroutine you will need to use variables for various tasks. In portable code you do not want the name you chose for such a variable to clash with a variable of the same name in the main program. To this end you can define a variable using `LOCAL` within the subroutine.

For example, this is our `FLASH` subroutine but this time we have extended it to take an argument (`nbr`) that specifies how many times to flash the LED.

```
SUB FLASH ( nbr )
  LOCAL INTEGER count
  SETPIN 2, DOUT
  FOR count = 1 TO nbr
    PIN(2) = 1
    PAUSE 100
    PIN(2) = 0
    PAUSE 150
  NEXT count
END SUB
```

The counting variable (`count`) is declared as `LOCAL` within the subroutine which means that (like the argument list) it only exists within the subroutine and will vanish when the subroutine exits. You can have a variable called `count` in your main program and it will be different from the variable `count` in your subroutine.

If you do not declare the variable as `LOCAL` within the subroutine and `OPTION EXPLICIT` is not in force it will be created within your program and be visible in your main program and subroutines, just like a normal variable.

You can also use local variables in the target for `GOSUB`s. For example:

```
GOSUB MySub
...
MySub:
  LOCAL X, Y
  FOR X = 1 TO ...
    FOR Y = 5 TO ...
      <statements>
    RETURN
```

The variables `X` and `Y` will only be valid until the `RETURN` statement is reached and will be different from variables with the same name in the main body of the program.

Defined Functions

Defined functions are similar to defined subroutines with the main difference being that the function is used to return a value in an expression. For example, if you wanted a function to convert a temperature from degrees Celsius to Fahrenheit you could define:

```
FUNCTION Fahrenheit(C)
  Fahrenheit = C * 1.8 + 32
END FUNCTION
```

Then you could use it in an expression:

```
Input " Enter a temperature in Celsius: ", t
PRINT "That is the same as" Fahrenheit(t) "F"
```

You could also define the reverse:

```
FUNCTION Celsius(F)
  Celsius = (F - 32) * 0.5556
END FUNCTION
```

The rules for the argument list in a function are similar to subroutines. The only difference is that brackets are required around the argument list when you are calling a function, even if there are no arguments (they are optional when calling a subroutine).

To return a value from the function you assign a value to the function's name within the function. If the function's name is terminated with a `$`, a `%` or a `!` the function will return that type, otherwise it will return whatever the `OPTION DEFAULT` is set to.

You can also specify the type of the function by adding AS <type> to the end of the function definition. For example:

```
FUNCTION Fahrenheit(C) AS FLOAT
```

The suffix ! specifies floating point so you can also use this:

```
FUNCTION Fahrenheit!(C)
```

Within the function the function's name acts like a standard variable (a float in this case).

As another example, let us say that you need a function to format time in the AM/PM format:

```
FUNCTION MyTime$(hours, minutes)
  LOCAL h
  h = hours
  IF hours > 12 THEN h = h - 12
  MyTime$ = STR$(h) + ":" + STR$(minutes)
  IF hours <= 12 THEN
    MyTime$ = MyTime$ + "AM"
  ELSE
    MyTime$ = MyTime$ + "PM"
  ENDIF
END FUNCTION
```

As you can see, the function name is used as an ordinary local variable inside the subroutine. It is only when the function returns that the value assigned to MyTime\$ is made available to the expression that called it. This example also illustrates that you can use local variables within functions just like subroutines.

Passing Arguments by Reference

If you use an ordinary variable (ie, not an expression) as the value when calling a subroutine or a function, the argument within the subroutine/function will point back to the variable used in the call and any changes to the argument will also be made to the supplied variable. This is called passing arguments by reference.

For example, you might define a subroutine to swap two values, as follows:

```
SUB Swap a, b
  LOCAL t
  t = a
  a = b
  b = t
END SUB
```

In your calling program you would use variables for both arguments:

```
Swap nbr1, nbr2
```

And the result will be that the values of nbr1 and nbr2 will be swapped.

Unless you need to return a value via the argument you should not use an argument as a general purpose variable inside a subroutine or function. This is because another user of your routine may unwittingly use a variable in their call and that variable will be "magically" changed by your routine. It is much safer to assign the argument to a local variable and manipulate that instead.

Passing Arrays

Single elements of an array can be passed to a subroutine or function and they will be treated the same as a normal variable. For example, this is a valid way of calling the Swap subroutine (discussed above):

```
Swap dat(i), dat(i + 1)
```

This type of construct is often used in sorting arrays.

You can also pass one or more complete arrays to a subroutine or function by specifying the array with empty brackets instead of the normal dimensions. For example, a (). In the subroutine or function definition the associated parameter must also be specified with empty brackets. The type (ie, float, integer or string) of the argument supplied and the parameter in the definition must be the same.

In the subroutine or function the array will inherit the dimensions of the array passed and these must be respected when indexing into the array. If required the dimensions of the array could be passed as additional arguments to the subroutine or function so it could correctly manipulate the array. The array is passed by reference which means that any changes made to the array within the subroutine or function will also apply to the supplied array.

For example, when the following is run the words "Hello World" will be printed out:

```
DIM MyStr$(5, 5)
MyStr$(4, 4) = "Hello" : MyStr$(4, 5) = "World"
Concat MyStr$()
PRINT MyStr$(0, 0)

SUB Concat arg$()
    arg$(0,0) = arg$(4, 4) + " " + arg$(4, 5)
END SUB
```

Early Exit

There can be only one END SUB or END FUNCTION for each definition of a subroutine or function. To exit early from a subroutine (ie, before the END SUB command has been reached) you can use the EXIT SUB command. This has the same effect as if the program reached the END SUB statement. Similarly you can use EXIT FUNCTION to exit early from a function.

Example of a Defined Function

There is often the need for a special command or function to be implemented in MMBasic but in many cases these can be constructed using a defined subroutine or function which will then act exactly the same as a built in command or function.

For example, sometimes there is a requirement for a TRIM function which will trim specified characters from the start and end of a string. The following provides an example of how to construct such a simple function in MMBasic.

The first argument to the function is the string to be trimmed and the second is a string containing the characters to trim from the first string. RTrim\$() will trim the specified characters from the end of the string, LTrim\$() from the beginning and Trim\$() from both ends.

```
' trim any characters in c$ from the start and end of s$
Function Trim$(s$, c$)
    Trim$ = RTrim$(LTrim$(s$, c$), c$)
End Function

' trim any characters in c$ from the end of s$
Function RTrim$(s$, c$)
    RTrim$ = s$
    Do While Instr(c$, Right$(RTrim$, 1))
        RTrim$ = Mid$(RTrim$, 1, Len(RTrim$) - 1)
    Loop
End Function

' trim any characters in c$ from the start of s$
Function LTrim$(s$, c$)
    LTrim$ = s$
    Do While Instr(c$, Left$(LTrim$, 1))
        LTrim$ = Mid$(LTrim$, 2)
    Loop
End Function
```

As an example of using these functions:

```
S$ = "    ****23.56700  "
PRINT Trim$(s$, " ")
```

Will give "****23.56700"

```
PRINT Trim$(s$, " *0")
```

Will give "23.567"

```
PRINT LTrim$(s$, " *0")
```

Will give "23.56700"

Special Functions and the Library

There are a number of features of the Micromite that enable the advanced user to add features to MMBasic and perform special operations at startup. Most programs will not need to use these features but they are handy for the advanced user who needs more control over the Micromite.

Embedded C Routines

It is possible to add program modules that are written in the C language or MIPS assembler to MMBasic. They are called CFunctions or CSubs and to the BASIC program they look the same as the MMBasic built in functions and subroutines. Generally these modules can run much faster than a BASIC program and can more easily access the special hardware features of the PIC32 microcontroller.

The firmware distribution for the Micromite includes a subdirectory titled "Embedded C Modules" which contains a selection of embedded C routines and fonts plus notes on how use this feature and write your own embedded C modules and create embedded fonts.

The Library

Using the LIBRARY feature it is possible to create BASIC functions, subroutines and embedded fonts and add them to MMBasic to make them permanent and part of the language. For example, you might have written a series of subroutines and functions that perform sophisticated bit manipulation; these could be stored as a library and become part of MMBasic and perform the same as other built in functions that are already part of the language. An embedded font can also be added the same way and used just like a normal font.

To install components into the library you need to write and test the routines as you would with any normal BASIC routines. When you are satisfied that they are working correctly you can use the LIBRARY SAVE command. This will transfer the routines (as many as you like) to a non visible part of flash memory where they will be available to any BASIC program but will not show when the LIST command is used and will not be deleted when a new program is loaded or NEW is used. However, the saved subroutines and functions can be called from within the main program and can even be run at the command prompt (just like a built in command or function).

Some points to note:

- Library routines act exactly like normal BASIC code and can consist of any number of subroutines, functions, embedded C routines and fonts. The only difference is that they do not show when a program is listed and are not deleted when a new program is loaded.
- Library routines can create and access global variables and are subject to the same rules as the main program – for example, respecting OPTION EXPLICIT if it is set.
- When the routines are transferred to the library MMBasic will compress them by removing comments, extra spaces, blank lines and the hex codes in embedded C routines and fonts. This makes the library space efficient, especially when loading large fonts. Following the save the program area is cleared.
- You can use the LIBRARY SAVE command multiple times. With each save the new contents of the program space are appended to the already existing code in the library.
- You can use line numbers in the library but you cannot use a line number on an otherwise empty line as the target for a GOTO, etc. This is because the LIBRARY SAVE command will remove any blank lines.
- You can use READ commands in the library but they will default to reading DATA statements in the main program memory. If you want to read from DATA statements in the library you must use the RESTORE command before the first READ command. This will reset the pointer to the library space.

To delete the routines in the library space you use the LIBRARY DELETE command. This will clear the space and return the flash memory used by the library back to the general pool used by normal programs. The only other way to delete a library is to reset MMBasic to its original configuration as described in the chapter "Resetting MMBasic" earlier in this manual.

As an example you could save the following into the library:

```
CFunction CPUSpeed
00000000 3c02bfb1 8c45f000 8c43f000 3c02003d 24420900 7ca51400 70a23002
3c040393 34848700 7c6316c0 00c41021 00621007 3c03029f 24636300 10430005
00402021 00002821 00801021 03e00008 00a01821 3c0402dc 34846c00 00002821
00801021 03e00008 00a01821
End CFunction
```

This would have the effect of adding a new function (called CPUSpeed) to MMBasic. You could even run it at the command prompt:

```
> PRINT CPUSpeed()  
40000000
```

You can see what is in the library by using the **LIBRARY LIST** command which will list the contents of the library space. In addition the **MEMORY** command can be used to display the amount of flash memory used by the library.

Program Initialisation

The library can also include code that is not contained within a subroutine or function. This code (if it exists) will be run automatically before a program starts running (ie, via the **RUN** command). This feature can be used to initialise constants or setup MMBasic in some way. For example, if you wanted to set some constants you could include the following lines in the library code:

```
CONST TRUE = 1  
CONST FALSE = 0
```

For all intents and purposes the identifiers **TRUE** and **FALSE** have been added to the language and will be available to any program that is run on the Micromite.

MM.STARTUP

There may be a need to execute some code on initial power up, regardless of the program in main memory. Perhaps to initialise some hardware, set some options or print a custom startup banner. This can be accomplished by creating a subroutine with the name **MM.STARTUP** and saving it in the library space (see above). When the Micromite is first powered up or reset it will search for this subroutine and, if found, it will be run once.

For example, if the Micromite has a real time clock attached, the library could contain the following code:

```
SUB MM.STARTUP  
    RTC GETTIME  
END SUB
```

This would cause the internal clock within MMBasic to be set to the current time on every power up or reset.

Using **MM.STARTUP** is similar to using the **OPTION AUTORUN** feature, the difference being that the **AUTORUN** option will cause the whole program in memory to be run from the start where **MM.STARTUP** will just run the code within the subroutine. The **AUTORUN** option and **MM.STARTUP** can be used together and in that case the **MM.STARTUP** subroutine is run first, then the program in main memory.

Note that you should not use **MM.STARTUP** for general setup of MMBasic (like dimensioning arrays, opening communication channels, etc) before running a program. The reason is that when you use the **RUN** command MMBasic will clear the interpreter's state ready for a fresh start. If you do want to setup MMBasic like this you can place the code for this in the **LIBRARY** (but not in a subroutine or function) as this is run after the **RUN** command has reset the interpreter's state but before the program in main memory is run.

MM.PROMPT

If a subroutine with this name exists it will be automatically executed by MMBasic instead of displaying the command prompt. This can be used to display a custom prompt, set colours, define variables, etc all of which will be active at the command prompt.

This subroutine can be located in the library space (recommended) or in the main program.

Note that MMBasic will clear all variables and I/O pin settings when a program is run so anything set in this subroutine will only be valid for commands typed at the command prompt (ie, in immediate mode). To initialise variables, constants, communications, etc for use inside a BASIC program the code for this should be placed in the **LIBRARY** (but not in a subroutine or function).

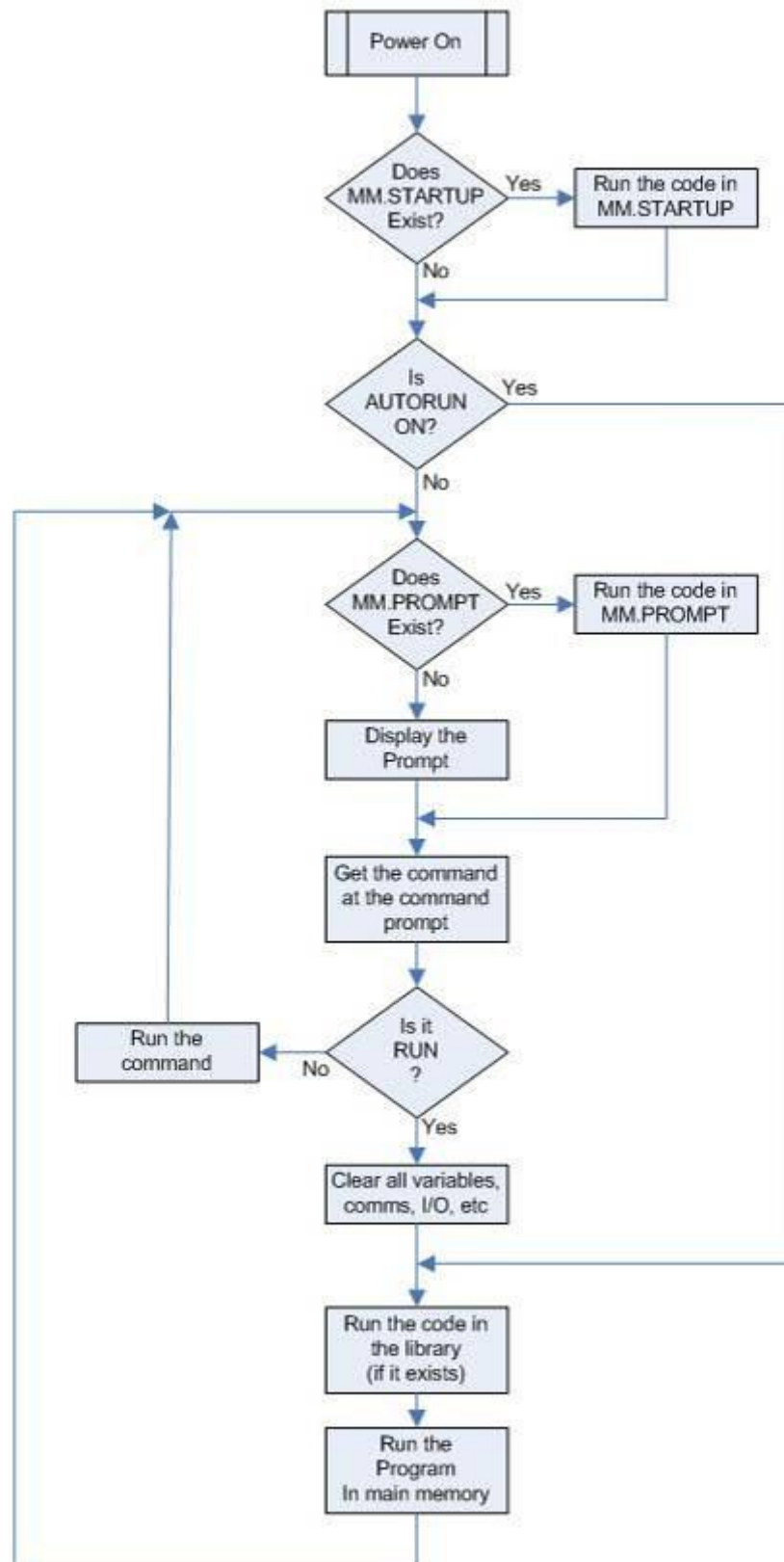
As an example the following will display a custom prompt:

```
SUB MM.PROMPT  
    PRINT TIME$ "> ";  
END SUB
```

Note that while constants can be defined they will not be visible because a constant defined inside a subroutine is local to a subroutine. However, **DIM** will create variables that are global that that should be used instead.

Flow Diagram

The operation of MMBasic at startup and the interaction between the library and the special functions is best illustrated using a flow diagram. The following is a high level diagram (for example, it does not show the complications caused by the CONTINUE command) but it does place the functions of MM.STARTUP and MM.PROMPT into context:



Electrical Characteristics

Power Supply

Voltage range:	2.3 to 3.6V (3.3V nominal). Absolute maximum 4.0V.
Current draw:	31 mA to 6 mA depending on the clock speed.
Current in sleep:	40 μ A (plus current draw from the I/O pins).

Digital Inputs

Logic Low:	0 to 0.65V
Logic High:	2.5V to 3.3V on normal pins 2.5V to 5.5V on pins rated at 5V
Input Impedance:	>1 M Ω . All digital inputs are Schmitt Trigger buffered.
Frequency Response:	Up to 300 kHz (pulse width 20 nS or more) on the counting inputs (pins 15 to 18).

Analog Inputs

Voltage Range:	0 to 3.3V
Accuracy:	Analog measurements are referenced to the supply voltage on pin 28 and the ground on pin 27. If the supply voltage is precisely 3.3V the typical accuracy of readings will be $\pm 1\%$.
Input Impedance:	>1 M Ω (for accurate readings the source impedance should be <5K)

Digital Outputs

Typical current draw or sink ability on any I/O pin:	10 mA
Absolute maximum current draw or sink on any I/O pin:	15 mA
Absolute maximum current draw or sink for all I/O pins combined:	200 mA
Maximum open collector voltage:	5.5V

Timing Accuracy

All timing functions (the timer, tick interrupts, PWM frequency, baud rate, etc) are dependent on the internal clock. The Micromite uses a fast RC oscillator which has a specified tolerance of $\pm 0.9\%$ but typically is within $\pm 0.1\%$ at 24°C.

PWM Output

Frequency range:	20 Hz to 500 kHz
Duty cycle:	0% to 100% with 0.1% resolution below 25 kHz

Serial Communications Ports

Console:	Default 38400 baud. Range is 100 bps to 230400 bps (at 40 MHz).
COM ports	Default 9600 baud. Range is 10 bps to 230400 bps (at 40 MHz). The maximum is limited by the clock speed. See Appendix A for details.

Other Communications Ports

SPI	10 Hz to 10 MHz (at 40 MHz). Limited to one quarter of the clock speed.
I ² C	10kHz to 400 kHz.
1-Wire:	Fixed at 15 kHz.

Flash Endurance

Over 20,000 erase/write cycles.

Every program save incurs one erase/write cycle. In a normal program development it is highly unlikely that more than a few hundred program saves would be required.

Saved variables (VAR SAVE command) and configuration options (the OPTION command) also use one erase/write cycle each time the command is used. Usage of the VAR SAVE command should be limited to an average of once a day over the entire life of the chip (50 years).

MMBasic Characteristics

Naming Conventions

Command names, function names, labels, variable names, etc are not case sensitive, so that "Run" and "RUN" are equivalent and "dOO" and "Doo" refer to the same variable.

The type of a variable can be specified in the DIM command or by adding a suffix to the end of the variable's name. For example the suffix for an integer is '%' so if a variable called nbr% is automatically created it will be an integer. There are three types of variables:

1. Floating point. These can store a number with a decimal point and fraction (eg, 45.386) and also very large numbers. However, they will lose accuracy when more than seven significant digits are stored or manipulated. The suffix is '!' and floating point is the default when a variable is created without a suffix
2. 64-bit integer. These can store numbers with up to 19 decimal digits without losing accuracy but they cannot store fractions (ie, the part following the decimal point). The suffix for an integer is '%'
3. Strings. These will store a string of characters (eg, "Tom"). The suffix for a string is the '\$' symbol (eg, name\$, s\$, etc) Strings can be up to 255 characters long.

Variable names and labels can start with an alphabetic character or underscore and can contain any alphabetic or numeric character, the period (.) and the underscore (_). They may be up to 32 characters long. A variable name or a label must not be the same as a command or a function or one of the following keywords: THEN, ELSE, TO, STEP, FOR, WHILE, UNTIL, MOD, NOT, AND, OR, XOR, AS. Eg, step = 5 is illegal.

Constants

Numeric constants may begin with a numeric digit (0-9) for a decimal constant, &H for a hexadecimal constant, &O for an octal constant or &B for a binary constant. For example &B1000 is the same as the decimal constant 8. Constants that start with &H, &O or &B are always treated as 64-bit integer constants.

Decimal constants may be preceded with a minus (-) or plus (+) and may be terminated with 'E' followed by an exponent number to denote exponential notation. For example 1.6E+4 is the same as 16000.

If the decimal constant contains a decimal point or an exponent, it will be treated as a floating point constant; otherwise it will be treated as a 64-bit integer constant.

String constants are surrounded by double quote marks ("). Eg, "Hello World".

Operators and Precedence

The following operators, in order of precedence, are recognised. Operators that are on the same level (for example + and -) are processed with a left to right precedence as they occur on the program line.

Arithmetic operators:

^	Exponentiation (eg, b^n means b^n)
* / \ MOD	Multiplication, division, integer division and modulus (remainder)
+ -	Addition and subtraction

Shift operators:

x << y x >> y	These operate in a special way. << means that the value returned will be the value of x shifted by y bits to the left while >> means the same only right shifted. They are integer functions and any bits shifted off are discarded and any bits introduced are set to zero.
------------------	--

Logical operators:

NOT	invert the logical value on the right (eg, NOT a=b is a<>b)
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version)
=	equality
AND OR XOR	Conjunction, disjunction, exclusive or

The operators AND, OR and XOR are integer bitwise operators. For example PRINT (3 AND 6) will output 2. The other logical operations result in the integer 0 (zero) for false and 1 for true. For example the statement PRINT 4 >= 5 will print the number zero on the output and the expression A = 3 > 2 will store +1 in A. The NOT operator will invert the logical value on its right (it is not a bitwise invert). It is also the highest in precedence so it will bind tightly to the next value. For normal use the logic expression to be negated should be placed in brackets. For example, IF NOT (A = 3 OR A = 8) THEN ...

String operators:

+	Join two strings
<> < > <= =< >= =>	Inequality, less than, greater than, less than or equal to, less than or equal to (alternative version), greater than or equal to, greater than or equal to (alternative version)
=	Equality

String comparisons respect case. For example "A" is greater than "a".

Implementation Characteristics

Maximum program size (as plain text) is 53KB. Note that MMBasic tokenises the program when it is stored in flash so the final size in flash might vary from the plain text size.

Maximum length of a command line is 255 characters.

Maximum length of a variable name or a label is 32 characters.

Maximum number of dimensions to an array is 8.

Maximum number of arguments to commands that accept a variable number of arguments is 50.

Maximum number of nested FOR...NEXT loops is 15.

Maximum number of nested DO...LOOP commands is 15.

Maximum number of nested GOSUBs, subroutines and functions (combined) is 50.

Maximum number of nested multiline IF...ELSE...ENDIF commands is 10.

Maximum number of user defined subroutines and functions (combined): 100 (200 in the Micromite Plus)

Maximum number of interrupt pins that can be configured: 10

Numbers are stored and manipulated as single precision floating point numbers or 64-bit signed integers. The maximum floating point number allowable is 3.40282347e+38 and the minimum is 1.17549435e-38.

The range of 64-bit integers (whole numbers) that can be manipulated is ± 9223372036854775807 .

Maximum string length is 255 characters.

Maximum line number is 65000.

Maximum number of background pulses launched by the PULSE command is 5.

Compatibility

MMBasic implements a large subset of Microsoft's GW-BASIC. There are numerous differences due to physical and practical considerations but most standard BASIC commands and functions are essentially the same. An online manual for GW-BASIC is available at <http://www.antonis.de/qbebooks/gwbasman/index.html> and this provides a more detailed description of the commands and functions.

MMBasic also implements a number of modern programming structures documented in the ANSI Standard for Full BASIC (X3.113-1987) or ISO/IEC 10279:1991. These include SUB/END SUB, the DO WHILE ... LOOP, the SELECT...CASE statements and structured IF .. THEN ... ELSE ... ENDIF statements.

Predefined Read Only Variables

These variables are set by MMBasic and cannot be changed by the running program.

MM.VER	The version number of the firmware as a floating point number in the form aa.bb.cc where aa is the major version number, bb is the minor version number and cc is the revision number. For example version 5.03.00 will return 5.3 and version 5.03.01 will return 5.0301.
MM.DEVICE\$	A string representing the device or platform that MMBasic is running on. Currently this variable will contain one of the following: "Maximite" on the standard Maximite and compatibles. "Colour Maximite" on the Colour Maximite and UBW32. "DuinoMite" when running on one of the DuinoMite family. "DOS" when running on Windows in a DOS box. "Generic PIC32" for the generic version of MMBasic on a PIC32. "Micromite" on the PIC32MX150/250 "Micromite MkII" on the PIC32MX170/270 "Micromite Plus" on the PIC32MX470 "Micromite Extreme" on the PIC32MZ series
MM.ERRNO MM.ERRMSG\$	If a statement caused an error which was ignored these variables will be set accordingly. MM.ERRNO is a number where non zero means that there was an error and MM.ERRMSG\$ is a string representing the error message that would have normally been displayed on the console. They are reset to zero and an empty string by RUN, ON ERROR IGNORE or ON ERROR SKIP.
MM.HRES MM.VRES	Integers representing the horizontal and vertical resolution of the LCD display panel (if configured) in pixels.
MM.FONTHEIGHT MM.FONTWIDTH	Integers representing the height and width of the current font (in pixels).
MM.WATCHDOG	An integer which is true if MMBasic was restarted as the result of a Watchdog timeout (see the WATCHDOG command). False if MMBasic started up normally.
MM.I2C	Following an I ² C write or read command this integer variable will be set to indicate the result of the operation as follows: 0 = The command completed without error. 1 = Received a NACK response 2 = Command timed out
MM.ONEWIRE	Following a 1-Wire reset function this integer variable will be set to indicate the result of the operation as follows: 0 = Device not found. 1 = Device found

Commands

Note that the commands related to the I²C, 1-Wire, and SPI communications functions are not listed here but are described in the appendices at the end of this document.

Square brackets indicate that the parameter or characters are optional.

' (single quotation mark)	Starts a comment and any text following it will be ignored. Comments can be placed anywhere on a line.
? (question mark)	Shortcut for the PRINT command.
AUTOSAVE	<p>Enter automatic program entry mode.</p> <p>This command will take lines of text from the console serial input and save them to memory. This mode is terminated by entering Control-Z which will then cause the received data to be saved into program memory overwriting the previous program.</p> <p>At any time this command can be aborted by Control-C which will leave program memory untouched.</p> <p>This is one way of transferring a BASIC program into the Micromite. The program to be transferred can be pasted into a terminal emulator and this command will capture the text stream and store it into program memory. It can also be used for entering a small program directly at the console input.</p>
BOX x, y, w, h [, lw] [,c] [,fill]	<p>Draws a box on the attached LCD panel with the top left hand corner at 'x' and 'y' with a width of 'w' pixels and a height of 'h' pixels.</p> <p>'lw' is the width of the sides of the box and can be zero. It defaults to 1.</p> <p>'c' specifies the colour and defaults to the default foreground colour if not specified.</p> <p>'fill' is the fill colour. It can be omitted or set to -1 in which case the box will not be filled.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
CIRCLE x, y, r [,lw] [, a] [, c] [, fill]	<p>Draw a circle on the video output centred at 'x' and 'y' with a radius of 'r' on the attached LCD panel. 'lw' is optional and is the line width (defaults to 1). 'c' is the optional colour and defaults to the current foreground colour if not specified.</p> <p>The optional 'a' is a floating point number which will define the aspect ratio. If the aspect is not specified the default is 1.0 which gives a standard circle</p> <p>'fill' is the fill colour. It can be omitted or set to -1 in which case the box will not be filled.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
CLS [colour]	Clears the LCD panel's screen. Optionally 'colour' can be specified which will be used for the background when clearing the screen.
COLOUR fore [, back] or COLOR fore [, back]	Sets the default colour for commands (PRINT, etc) that display on the on the attached LCD panel. 'fore' is the foreground colour, 'back' is the background colour. The background is optional and if not specified will default to black.
CSUB name(type [, type]) rtype hex [[hex[...] hex [[hex[...] END CSUB	<p>Defines the binary code for an embedded machine code program module written in C or MIPS assembler. The module will appear in MMBasic as the command or function 'name' and can be used in the same manner as a built-in command or function.</p> <p>This command specifies the hex codes for the module. This code is automatically programmed into MMBasic when the program is saved. Each 'hex' must be exactly eight hex digits representing the bits in a 32-bit word.</p>

<p>or</p> <p>CFUNCTION name type [,type] hex [[hex[...] hex [[hex[...] END CFUNCTION</p>	<ul style="list-style-type: none"> • Each 'hex' word must be separated by one or more spaces and multiple lines of 'hex' words can be used. The command must be terminated by a matching END CSUB or END CFUNCTION. • The first 'hex' word must be the offset (in 32-bit words) to the entry point of the embedded routine (usually the function main()). • Multiple embedded routines can be used in a program with each defining a different module with a different 'name'. • During execution MMBasic will skip over any CSUB or CFUNCTION commands so they can be placed anywhere in the program. <p>Any errors in the data format will be reported when the program is saved.</p> <p>The type of each parameter can be specified in the definition. For example:</p> <pre>CSub MySub integer, integer, string</pre> <p>This specifies that there will be three parameters, the first two being integers and the third a string.</p> <p>As well as defining the types of the parameters a CFunction can also specify the type of the value returned. For example, the following returns a string:</p> <pre>CFunction MyFuncnt(integer, string) string</pre> <p>The 'name' created by these commands can be used as a normal command or function within MMBasic with a few caveats:</p> <ul style="list-style-type: none"> • Up to ten values can be specified as parameters ('arg1', 'arg2', etc) and they will be passed to the embedded C routine as pointers to the memory space allocated to each value (ie, the result of the expression). • If a variable or array is specified as an argument the C routine will receive a pointer to the memory allocated to the variable or array and the C routine can change this memory to return a value to the caller. • In the case of arrays, they should be passed with empty brackets. eg, arg(). In the C function the argument will be supplied as a pointer to the first element of the array. <p>For more details refer to the "Embedded C Modules" documentation in the Micromite firmware file.</p>
<p>CLEAR</p>	<p>Delete all variables and recover the memory used by them.</p> <p>See ERASE for deleting specific array variables.</p>
<p>CLOSE [#]nbr [, [#]nbr] ...</p>	<p>Close the serial communications port(s) previously opened with the file number 'nbr'. The # is optional. Also see the OPEN command.</p>
<p>CONST id = expression [, id = expression] ... etc</p>	<p>Create a constant identifier which cannot be changed once created.</p> <p>'id' is the identifier which follows the same rules as for variables. The identifier can have a type suffix (!, %, or \$) but it is not required. If it is specified it must match the type of 'expression'.</p> <p>'expression' is the value of the identifier and it can be a normal expression (including user defined functions) which will be evaluated when the constant is created.</p> <p>A constant defined outside a sub or function is global and can be seen throughout the program. A constant defined inside a sub or function is local to that routine and will hide a global constant with the same name.</p>
<p>CONTINUE</p>	<p>Resume running a program that has been stopped by an END statement, an error, or CTRL-C. The program will restart with the next statement following the previous stopping point.</p> <p>Note that it is not always possible to resume the program correctly – this particularly applies to complex programs with graphics, nested loops and/or nested subroutines and functions.</p>

CONTINUE DO or CONTINUE FOR	Skip to the end of a DO/LOOP or a FOR/NEXT loop. The loop condition will then be tested and if still valid the loop will continue with the next iteration.
CPU speed	<p>Set the clock speed of the processor.</p> <p>'speed' is set in MHz and on the 28/44 pin Micromite it can be either 48, 40, 30, 20, 10, or 5.</p> <p>On the Micromite Plus it can be 120, 100, 80, 60, 48, 40, 30, 20, 10 or 5.</p> <p>Current drawn by the chip is proportional to the clock speed, so by halving the clock speed the current drain is roughly halved. The default speed of the CPU when power is applied is 40MHz on the 28/44 pin Micromite and 100MHz on the Micromite Plus.</p> <p>When the speed is changed all timing functions in MMBasic will be automatically corrected to keep the correct time and the console baud rate will be unchanged. The serial communications ports can remain open during the speed change and their speed will be adjusted accordingly. Note that there may be a glitch while changing speed and some characters may be lost or corrupted.</p> <p>The speed of any SPI, I²C and PWM functions open at the time will change with the clock speed. For this reason they should be closed before this command is used and reopened after.</p>
CPU SLEEP or CPU SLEEP seconds [, abortpin]	<p>Put the CPU to sleep. In this mode the running program will be halted and the current drain reduced to about 40 µA.</p> <p>In the first form the WAKEUP pin (see the pinout tables at the start of this manual) will be automatically configured as a digital input and any change in its state (ie, from high to low or low to high) will wakeup the CPU. The time required to "wake up" in this mode is less than 1 ms.</p> <p>The IR command shares the WAKEUP pin and if it is running the CPU will be awakened by the remote key press and MMBasic will immediately decode the signal and execute the IR interrupt.</p> <p>In the second form (CPU SLEEP seconds) the command will put the CPU to sleep for the specified number of 'seconds' (accuracy is ±20%). The TIMER function and the internal clock/calendar will be updated when the sleep finishes.</p> <p>The timed sleep can be terminated early if 'abortpin' is specified. This can be any I/O pin and any change in its state (ie, from high to low or low to high) will abort the sleep. It can take up to a second for the abort signal to be recognised so the change of state must be maintained for at least this time.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The CPU will go to sleep in the middle of the SLEEP command and when awakened continue with normal program execution. • All communications (serial, SPI, I2C and 1-Wire) and PWM will be frozen during sleep. When the CPU comes out of sleep they will resume normal processing. It is recommended that they be closed before entering sleep as they will add to the current drawn by the chip in sleep. • External circuitry and program features can cause extra current drain while in sleep. See the section <i>Micromite Special Features</i> for the steps that should be taken to minimise the current drawn during sleep. • All timing functions will freeze during the sleep, this includes the real time clock and background pulse commands. • CTRL-C on the console will <u>not</u> bring the chip out of sleep.

CPU RESTART	<p>Will force a restart of the processor.</p> <p>This will clear all variables and reset everything (eg, timers, COM ports, I²C, etc) similar to a power up situation but without the power up banner.</p> <p>If OPTION AUTORUN has been set the program in memory will restart.</p>
DATA constant[,constant]...	<p>Stores numerical and string constants to be accessed by READ.</p> <p>In general string constants should be surrounded by double quotes ("). An exception is when the string consists of just alphanumeric characters that do not represent MMBasic keywords (such as THEN, WHILE, etc). In that case quotes are not needed.</p> <p>Numerical constants can also be expressions such as 5 * 60.</p>
DATE\$ = "DD-MM-YY" or DATE\$ = "DD/MM/YY"	<p>Set the date of the internal clock/calendar.</p> <p>DD, MM and YY are numbers, for example: DATE\$ = "28-7-2014"</p> <p>The date is set to "01-01-2000" on power up.</p>
DEFINEFONT #Nbr hex [[hex[...] hex [[hex[...] END DEFINEFONT	<p>This will define an embedded font which can be used alongside or to replace the built in font(s) used on an attached LCD panel. These work exactly same as the built in fonts (ie, selected using the FONT command or specified in the TEXT command).</p> <p>'#Nbr' is the font's reference number (from 1 to 16). It can be the same number as a built in font and in that case it will replace the built in font.</p> <p>Each 'hex' must be exactly eight hex digits and be separated by spaces or new lines from the next.</p> <ul style="list-style-type: none"> • Multiple lines of 'hex' words can be used with the command terminated by a matching END DEFINEFONT. • Multiple embedded fonts can be used in a program with each defining a different font with a different font number. • During execution MMBasic will skip over any DEFINEFONT commands so they can be placed anywhere in the program. • Any errors in the data format will be reported when the program is saved.
DIM [type] decl [,decl]... where 'decl' is: var [length] [type] [init] 'var' is a variable name with optional dimensions 'length' is used to set the maximum size of the string to 'n' as in LENGTH n 'type' is one of FLOAT or INTEGER or STRING (the type can be prefixed by the keyword AS - as in AS FLOAT) 'init' is the value to initialise the variable and consists of: = <expression> For a simple variable one expression is used, for an array a list of comma separated expressions surrounded by brackets is used.	<p>Declares one or more variables (ie, makes the variable name and its characteristics known to the interpreter).</p> <p>When OPTION EXPLICIT is used (as recommended) the DIM, LOCAL or STATIC commands are the only way that a variable can be created. If this option is not used then using the DIM command is optional and if not used the variable will be created automatically when first referenced.</p> <p>The type of the variable (ie, string, float or integer) can be specified in one of three ways:</p> <p>By using a type suffix (ie, !, % or \$ for float, integer or string). For example:</p> <pre>DIM nbr%, amount!, name\$</pre> <p>By using one of the keywords FLOAT, INTEGER or STRING immediately after the command DIM and before the variable(s) are listed. The specified type then applies to all variables listed (ie, it does not have to be repeated). For example:</p> <pre>DIM STRING first_name, last_name, city</pre> <p>By using the Microsoft convention of using the keyword "AS" and the type keyword (ie, FLOAT, INTEGER or STRING) after each variable. If you use this method the type must be specified for each variable and can be changed from variable to variable.</p> <p>For example:</p> <pre>DIM amount AS FLOAT, name AS STRING</pre>

<p>Examples:</p> <pre> DIM nbr(50) DIM INTEGER nbr(50) DIM name AS STRING DIM a, b\$, nbr(100), strn\$(20) DIM a(5,5,5), b(1000) DIM strn\$(200) LENGTH 20 DIM STRING strn(200) LENGTH 20 DIM a = 1234, b = 345 DIM STRING strn = "text" DIM x%(3) = (11, 22, 33, 44)</pre>	<p>Floating point or integer variables will be set to zero when created and strings will be set to an empty string (ie, ""). You can initialise the value of the variable with something different by using an equals symbol (=) and an expression following the variable definition. For example:</p> <pre>DIM STRING city = "Perth", house = "Brick"</pre> <p>The initialising value can be an expression (including other variables) and will be evaluated when the DIM command is executed. See the chapter "Defining and Using Variables" for more examples of the syntax.</p> <p>As well as declaring simple variables the DIM command will also declare arrayed variables (ie, an indexed variable with a number of dimensions). Following the variable's name the dimensions are specified by a list of numbers separated by commas and enclosed in brackets. For example:</p> <pre>DIM array(10, 20)</pre> <p>Each number specifies the number of elements in each dimension. Normally the numbering of each dimension starts at 0 but the OPTION BASE command can be used to change this to 1.</p> <p>The above example specifies a two dimensional array with 11 elements (0 to 10) in the first dimension and 21 (0 to 20) in the second dimension. The total number of elements is 231 and because each floating point number requires 4 bytes a total of 924 bytes of memory will be allocated (integers are different and require 8 bytes per element).</p> <p>Strings will default to allocating 255 bytes (eg, characters) of memory for each element and this can quickly use up memory. In that case the LENGTH keyword can be used to specify the amount of memory to be allocated to each element and therefore the maximum length of the string that can be stored. This allocation ('n') can be from 1 to 255 characters.</p> <p>For example: DIM STRING s(5, 10) will declare a string array with 66 elements consuming 16,896 bytes of memory while:</p> <pre>DIM STRING s(5, 10) LENGTH 20</pre> <p>Will only consume 1,386 bytes of memory. Note that the amount of memory allocated for each element is n + 1 as the extra byte is used to track the actual length of the string stored in each element.</p> <p>If a string longer than 'n' is assigned to an element of the array an error will be produced. Other than this, string arrays created with the LENGTH keyword act exactly the same as other string arrays. This keyword can also be used with non array string variables but it will not save any memory.</p> <p>In the above example you can also use the Microsoft syntax of specifying the type after the length qualifier. For example:</p> <pre>DIM s(5, 10) LENGTH 20 AS STRING</pre> <p>Arrays can also be initialised when they are declared by adding an equals symbol (=) followed by a bracketed list of values at the end of the declaration. For example:</p> <pre> DIM INTEGER nbr(4) = (22, 44, 55, 66, 88) or DIM s\$(3) = ("foo", "boo", "doo", "zoo")</pre> <p>Note that the number of initialising values must match the number of elements in the array including the base value set by OPTION BASE. If a multi dimensioned array is initialised then the first dimension will be initialised first followed by the second, etc.</p>
<pre> DO <statements> LOOP</pre>	<p>This structure will loop forever; the EXIT DO command can be used to terminate the loop or control must be explicitly transferred outside of the loop by commands like GOTO or EXIT SUB (if in a subroutine).</p>
<pre> DO WHILE expression <statements> LOOP</pre>	<p>Loops while "expression" is true (this is equivalent to the older WHILE-WEND loop, also implemented in MMBasic). If, at the start, the expression is false the statements in the loop will not be executed, even once.</p>

DO <statements> LOOP UNTIL expression	Loops until the expression following UNTIL is true. Because the test is made at the end of the loop the statements inside the loop will be executed at least once, even if the expression is true.																												
EDIT	<p>Invoke the full screen editor.</p> <p>All the editing keys work with a VT100 terminal emulator so editing can also be accomplished over the console serial link. The editor has been tested with Tera Term and PuTTY running on a Windows PC.</p> <p>On entry the cursor will be automatically positioned at the last line edited or, if there was an error when running the program, the line that caused the error.</p> <p>The editing keys are:</p> <table> <tr> <td>Left/Right arrows</td><td>Moves the cursor within the line.</td></tr> <tr> <td>Up/Down arrows</td><td>Moves the cursor up or down a line.</td></tr> <tr> <td>Page Up/Down</td><td>Move up or down a page of the program.</td></tr> <tr> <td>Home/End</td><td>Moves the cursor to the start or end of the line. A second Home/End will move to the start or end of the program.</td></tr> <tr> <td>Delete</td><td>Delete the character over the cursor. This can be the line separator character and thus join two lines.</td></tr> <tr> <td>Backspace</td><td>Delete the character before the cursor.</td></tr> <tr> <td>Insert</td><td>Will switch between insert and overwrite mode.</td></tr> <tr> <td>Escape Key</td><td>Will close the editor without saving (confirms first).</td></tr> <tr> <td>F1</td><td>Save the edited text and exit.</td></tr> <tr> <td>F2</td><td>Save, exit and run the program.</td></tr> <tr> <td>F3</td><td>Invoke the search function.</td></tr> <tr> <td>SHIFT F3</td><td>Repeat the search using the text entered with F3.</td></tr> <tr> <td>F4</td><td>Mark text for cut or copy (see below).</td></tr> <tr> <td>F5</td><td>Paste text previously cut or copied.</td></tr> </table> <p>When in the mark text mode (entered with F4) the editor will allow you to use the arrow keys to highlight text which can be deleted, cut to the clipboard or simply copied to the clipboard. The status line will change to indicate the new functions of the function keys.</p> <p>The editor will work with lines wider than the screen but characters beyond the screen edge will not be visible. You can split such a line by inserting a new line character and the two lines can be later rejoined by deleting the inserted new line character.</p>	Left/Right arrows	Moves the cursor within the line.	Up/Down arrows	Moves the cursor up or down a line.	Page Up/Down	Move up or down a page of the program.	Home/End	Moves the cursor to the start or end of the line. A second Home/End will move to the start or end of the program.	Delete	Delete the character over the cursor. This can be the line separator character and thus join two lines.	Backspace	Delete the character before the cursor.	Insert	Will switch between insert and overwrite mode.	Escape Key	Will close the editor without saving (confirms first).	F1	Save the edited text and exit.	F2	Save, exit and run the program.	F3	Invoke the search function.	SHIFT F3	Repeat the search using the text entered with F3.	F4	Mark text for cut or copy (see below).	F5	Paste text previously cut or copied.
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ELSE	<p>Introduces a default condition in a multiline IF statement.</p> <p>See the multiline IF statement for more details.</p>																												
ELSEIF expression THEN or ELSE IF expression THEN	<p>Introduces a secondary condition in a multiline IF statement.</p> <p>See the multiline IF statement for more details.</p>																												
ENDIF or END IF	<p>Terminates a multiline IF statement.</p> <p>See the multiline IF statement for more details.</p>																												
END	End the running program and return to the command prompt.																												
END FUNCTION	<p>Marks the end of a user defined function. See the FUNCTION command.</p> <p>Each function must have one and only one matching END FUNCTION statement. Use EXIT FUNCTION if you need to return from a function from within its body.</p>																												

END SUB	<p>Marks the end of a user defined subroutine. See the SUB command.</p> <p>Each sub must have one and only one matching END SUB statement. Use EXIT SUB if you need to return from a subroutine from within its body.</p>
ERASE variable [,variable]...	<p>Deletes variables and frees up the memory allocated to them. This will work with arrayed variables and normal (non array) variables. Arrays can be specified using empty brackets (eg, dat ()) or just by specifying the variable's name (eg, dat).</p> <p>Use CLEAR to delete all variables at the same time (including arrays).</p>
ERROR [error_msg\$]	<p>Forces an error and terminates the program. This is normally used in debugging or to trap events that should not occur.</p>
EXIT DO EXIT FOR EXIT FUNCTION EXIT SUB	<p>EXIT DO provides an early exit from a DO...LOOP</p> <p>EXIT FOR provides an early exit from a FOR...NEXT loop.</p> <p>EXIT FUNCTION provides an early exit from a defined function.</p> <p>EXIT SUB provides an early exit from a defined subroutine.</p> <p>The old standard of EXIT on its own (exit a do loop) is also supported.</p>
FONT [#]font-number, scaling	<p>This will set the default font for displaying text on an LCD panel.</p> <p>Fonts are specified as a number. For example, #2 (the # is optional) See the chapter "Basic Drawing Commands" for details of the available fonts.</p> <p>'scaling' can range from 1 to 15 and will multiply the size of the pixels making the displayed character correspondingly wider and higher. Eg, a scale of 2 will double the height and width.</p>
FOR counter = start TO finish [STEP increment]	<p>Initiates a FOR-NEXT loop with the 'counter' initially set to 'start' and incrementing in 'increment' steps (default is 1) until 'counter' equals 'finish'.</p> <p>The 'increment' can be an integer or floating point number. Note that using a floating point fractional number for 'increment' can accumulate rounding errors in 'counter' which could cause the loop to terminate early or late.</p> <p>'increment' can be negative in which case 'finish' should be less than 'start' and the loop will count downwards.</p> <p>See also the NEXT command.</p>
FUNCTION xxx (arg1 [,arg2, ...]) [AS <type>} <statements> <statements> xxx = <return value> END FUNCTION	<p>Defines a callable function. This is the same as adding a new function to MMBasic while it is running your program.</p> <p>'xxx' is the function name and it must meet the specifications for naming a variable. The type of the function can be specified by using a type suffix (ie, xxx\$) or by specifying the type using AS <type> at the end of the functions definition. For example:</p> <pre> FUNCTION xxx (arg1, arg2) AS STRING </pre> <p>'arg1', 'arg2', etc are the arguments or parameters to the function (the brackets are always required, even if there are no arguments). An array is specified by using empty brackets. ie, arg3(). The type of the argument can be specified by using a type suffix (ie, arg1\$) or by specifying the type using AS <type> (ie, arg1 AS STRING) .</p> <p>The argument can also be another defined function or the same function if recursion is to be used (the recursion stack is limited to 50 nested calls).</p> <p>To set the return value of the function you assign the value to the function's name. For example:</p> <pre> FUNCTION SQUARE (a) SQUARE = a * a END FUNCTION </pre> <p>Every definition must have one END FUNCTION statement. When this is reached the function will return its value to the expression from which it was</p>

	<p>called. The command EXIT FUNCTION can be used for an early exit. You use the function by using its name and arguments in a program just as you would a normal MMBasic function. For example:</p> <pre>PRINT SQUARE (56.8)</pre> <p>When the function is called each argument in the caller is matched to the argument in the function definition. These arguments are available only inside the function.</p> <p>Functions can be called with a variable number of arguments. Any omitted arguments in the function's list will be set to zero or a null string.</p> <p>Arguments in the caller's list that are a variable (ie, not an expression or constant) will be passed by reference to the function. This means that any changes to the corresponding argument in the function will also be copied to the caller's variable. Arrays are passed by specifying the array name with empty brackets (eg, arg()) and are always passed by reference.</p> <p>You must not jump into or out of a function using commands like GOTO, GOSUB, etc. Doing so will have undefined side effects including the possibility of ruining your day.</p>
GOSUB target	Initiates a subroutine call to the target, which can be a line number or a label. The subroutine must end with RETURN.
GOTO target	Branches program execution to the target, which can be a line number or a label.
GUI BITMAP x, y, bits [, width] [, height] [, scale] [, c] [, bc]	<p>Displays the bits in a bitmap on an LCD panel starting at 'x' and 'y' on an attached LCD panel.</p> <p>'height' and 'width' are the dimensions of the bitmap as displayed on the LCD panel and default to 8x8.</p> <p>'scale' is optional and defaults to that set by the FONT command.</p> <p>'c' is the drawing colour and 'bc' is the background colour. They are optional and default to the current foreground and background colours.</p> <p>The bitmap can be an integer or a string variable or constant and is drawn using the first byte as the first bits of the top line (bit 7 first, then bit 6, etc) followed by the next byte, etc. When the top line has been filled the next line of the displayed bitmap will start with the next bit in the integer or string.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
GUI CALIBRATE	This command is used to calibrate the touch feature on an LCD panel. It will display a series of targets on the screen and wait for each one to be precisely touched.
GUI RESET LCDPANEL	Will reinitialise the configured LCD panel. Initialisation is automatically done when the Micromite starts up but in some circumstances it may be necessary to interrupt power to the LCD panel (eg, to save battery power) and this command can then be used to reinitialise the display.
GUI TEST LCDPANEL or GUI TEST TOUCH	<p>Will test the display or touch feature on an LCD panel.</p> <p>With GUI TEST LCDPANEL an animated display of colour circles will be rapidly drawn on top of each other.</p> <p>With GUI TEST TOUCH the screen will blank and wait for a touch which will cause a white dot to be placed on the display marking the touch position on the screen.</p>

IF expr THEN statement or IF expr THEN stmt ELSE stmt	<p>Evaluates the expression 'expr' and performs the THEN statement if it is true or skips to the next line if false. The optional ELSE statement is the reverse of the THEN test. This type of IF statement is all on one line.</p> <p>The 'THEN statement' construct can be also replaced with: GOTO linenumber label'.</p>
IF expression THEN <statements> [ELSEIF expression THEN <statements>] [ELSE <statements>] ENDIF	<p>Multiline IF statement with optional ELSE and ELSEIF cases and ending with ENDIF. Each component is on a separate line.</p> <p>Evaluates 'expression' and performs the statement(s) following THEN if the expression is true or optionally the statement(s) following the ELSE statement if false.</p> <p>The ELSEIF statement (if present) is executed if the previous condition is false and it starts a new IF chain with further ELSE and/or ELSEIF statements as required.</p> <p>One ENDIF is used to terminate the multiline IF.</p>
INPUT ["prompt\$";] var1 [,var2 [, var3 [, etc]]]	<p>Will take a list of values separated by commas (,) entered at the console and will assign them to a sequential list of variables.</p> <p>For example, if the command is: INPUT a, b, c And the following is typed on the keyboard: 23, 87, 66 Then a = 23 and b = 87 and c = 66</p> <p>The list of variables can be a mix of float, integer or string variables. The values entered at the console must correspond to the type of variable.</p> <p>If a single value is entered a comma is not required (however that value cannot contain a comma).</p> <p>'prompt\$' is a string constant (not a variable or expression) and if specified it will be printed first. Normally the prompt is terminated with a semicolon (;) and in that case a question mark will be printed following the prompt. If the prompt is terminated with a comma (,) rather than the semicolon (;) the question mark will be suppressed.</p>
INPUT #nbr, list of variables	<p>Same as above except that the input is read from a serial port previously opened for INPUT as 'nbr'. See the OPEN command.</p>
IR dev, key , int or IR CLOSE	<p>Decodes NEC or Sony infrared remote control signals.</p> <p>An IR Receiver Module is used to sense the IR light and demodulate the signal. It should be connected to the IR pin (see the pinout tables). This command will automatically set that pin to an input.</p> <p>The IR signal decode is done in the background and the program will continue after this command without interruption. 'dev' and 'key' should be numeric variables and their values will be updated whenever a new signal is received ('dev' is the device code transmitted by the remote and 'key' is the key pressed).</p> <p>'int' is a user defined subroutine that will be called when a new key press is received or when the existing key is held down for auto repeat. In the interrupt subroutine the program can examine the variables 'dev' and 'key' and take appropriate action.</p> <p>The IR CLOSE command will terminate the IR decoder and return the I/O pin to a not configured state.</p> <p>Note that for the NEC protocol the bits in 'dev' and 'key' are reversed. For example, in 'key' bit 0 should be bit 7, bit 1 should be bit 6, etc. This does not affect normal use but if you are looking for a specific numerical code provided by a manufacturer you should reverse the bits. This describes how to do it: http://www.thebackshed.com/forum/forum_posts.asp?TID=8367</p> <p>See the chapter "Special Hardware Devices" for more details.</p>

<p>KEYPAD var, int, r1, r2, r3, r4, c1, c2, c3 [, c4]</p> <p>or</p> <p>KEYPAD CLOSE</p>	<p>Monitor and decode key presses on a 4x3 or 4x4 keypad.</p> <p>Monitoring of the keypad is done in the background and the program will continue after this command without interruption. 'var' should be a numeric variable and its value will be updated whenever a key press is detected.</p> <p>'int' is a user defined subroutine that will be called when a new key press is received. In the interrupt subroutine the program can examine the variable 'var' and take appropriate action.</p> <p>r1, r2, r3 and r4 are pin numbers used for the four row connections to the keypad and c1, c2, c3 and c4 are the column connections. c4 is optional and is only used with 4x4 keypads. This command will automatically configure these pins as required.</p> <p>On a key press the value assigned to 'var' is the number of a numeric key (eg, '6' will return 6) or 10 for the * key and 11 for the # key. On 4x4 keypads the number 20 will be returned for A, 21 for B, 22 for C and 23 for D.</p> <p>The KEYPAD CLOSE command will terminate the keypad function and return the I/O pin to a not configured state.</p> <p>See the chapter "Special Hardware Devices" for more details.</p>
<p>LET variable = expression</p>	<p>Assigns the value of 'expression' to the variable. LET is automatically assumed if a statement does not start with a command.</p>
<p>LCD INIT d4, d5, d6, d7, rs, en</p> <p>or</p> <p>LCD line, pos, text\$</p> <p>or</p> <p>LCD CLEAR</p> <p>or</p> <p>LCD CLOSE</p>	<p>Display text on an LCD character display module. This command will work with most 1-line, 2-line or 4-line LCD modules that use the KS0066, HD44780 or SPLC780 controller (however this is not guaranteed).</p> <p>The LCD INIT command is used to initialise the LCD module for use. 'd4' to 'd7' are the I/O pins that connect to inputs D4 to D7 on the LCD module (inputs D0 to D3 should be connected to ground). 'rs' is the pin connected to the register select input on the module (sometimes called CMD). 'en' is the pin connected to the enable or chip select input on the module. The R/W input on the module should always be grounded. The above I/O pins are automatically set to outputs by this command.</p> <p>When the module has been initialised data can be written to it using the LCD command. 'line' is the line on the display (1 to 4) and 'pos' is the character location on the line (the first location is 1). 'text\$' is a string containing the text to write to the LCD display.</p> <p>'pos' can also be C8, C16, C20 or C40 in which case the line will be cleared and the text centred on a 8 or 16, 20 or 40 line display. For example:</p> <pre>LCD 1, C16, "Hello"</pre> <p>LCD CLEAR will erase all data displayed on the LCD and LCD CLOSE will terminate the LCD function and return all I/O pins to the not configured state.</p> <p>See the chapter "Special Hardware Devices" for more details.</p>
<p>LCD CMD d1 [, d2 [, etc]]</p> <p>or</p> <p>LCD DATA d1 [, d2 [, etc]]</p>	<p>These commands will send one or more bytes to an LCD display as either a command (LCD CMD) or as data (LCD DATA). Each byte is a number between 0 and 255 and must be separated by commas. The LCD must have been previously initialised using the LCD INIT command (see above).</p> <p>These commands can be used to drive a non standard LCD in "raw mode" or they can be used to enable specialised features such as scrolling, cursors and custom character sets. You will need to refer to the data sheet for your LCD to find the necessary command and data values.</p>
<p>LIBRARY SAVE</p> <p>or</p> <p>LIBRARY DELETE</p> <p>or</p> <p>LIBRARY LIST</p>	<p>The library is a special segment of program memory that can contain program code such as subroutines, functions and CFunctions. These routines are not visible to the programmer but are available to any program running on the Micromite and act the same as built in commands and functions in MMBasic. See the chapter "Special Functions and the Library" earlier in this manual for a full explanation.</p>

	<p>LIBRARY SAVE will take whatever is in normal program memory, compress it (remove redundant data such as comments) and append it to the library area (main program memory is then empty). The code in the library will not show in LIST or EDIT and will not be deleted when a new program is loaded or NEW is used.</p> <p>LIBRARY DELETE will remove the library and recover the memory used.</p> <p>LIBRARY LIST will list the contents of the library.</p> <p>Note that any code in the library that is not contained within a subroutine or function will be executed immediately before a program is run. This can be used to initialise constants, set options, etc.</p>
LINE x1, y1, x2, y2 [, LW [, C]]	<p>Draws a line starting at the coordinates 'x1' and 'y1' and ending at 'x2' and 'y2'.</p> <p>'LW' is the line's width and is only valid for horizontal or vertical lines. It defaults to 1 if not specified or if the line is a diagonal. 'C' is an integer representing the colour and defaults to the current foreground colour.</p>
LINE INPUT [prompt\$,] string-variable\$	<p>Reads an entire line from the console input into 'string-variable\$'.</p> <p>'prompt\$' is a string constant (not a variable or expression) and if specified it will be printed first.</p> <p>Unlike INPUT, this command will read a whole line, not stopping for comma delimited data items.</p> <p>A question mark is not printed unless it is part of 'prompt\$'.</p>
LINE INPUT #nbr, string-variable\$	<p>Same as above except that the input is read from a serial communications port previously opened for INPUT as 'nbr'. See the OPEN command.</p>
LIST or LIST ALL	<p>List a program on the serial console.</p> <p>LIST on its own will list the program with a pause at every screen full.</p> <p>LIST ALL will list the program without pauses. This is useful if you wish to transfer the program in the Micromite to a terminal emulator on a PC that has the ability to capture its input stream to a file.</p>
LOCAL variable [, variables] See DIM for the full syntax.	<p>Defines a list of variable names as local to the subroutine or function.</p> <p>This command uses exactly the same syntax as DIM and will create variables that will only be visible within the subroutine or function. They will be automatically discarded when the subroutine or function exits.</p>
LOOP [UNTIL expression]	<p>Terminates a program loop: see DO.</p>
MEMORY	<p>List the amount of memory currently in use. For example:</p> <pre>Flash: 21K (35%) Program (805 lines) 1K (1%) 2 CFunctions 1K (1%) 4 Saved Variables 37K (63%) Free</pre> <pre>RAM: 9K (16%) 5 Variables 18K (32%) General 26K (52%) Free</pre> <p>Notes:</p> <ul style="list-style-type: none"> • General memory is used by serial I/O buffers, etc. • Program memory is cleared by the NEW command. • Variables and the general memory spaces are cleared by many commands (eg, NEW, RUN, etc) as well as the specific commands CLEAR and ERASE. • Memory usage is rounded to the nearest 1K byte. • When a program is loaded it is first buffered in RAM which limits the

	maximum program size. MMBasic tokenises the program when it is stored in flash so the final size in flash might vary from this.
NEW	Deletes the program in flash and clears all variables.
NEXT [counter-variable] [, counter-variable], etc	<p>NEXT comes at the end of a FOR-NEXT loop; see FOR.</p> <p>The 'counter-variable' specifies exactly which loop is being operated on. If no 'counter-variable' is specified the NEXT will default to the innermost loop. It is also possible to specify multiple counter-variables as in:</p> <p>NEXT x, y, z</p>
ON ERROR ABORT or ON ERROR IGNORE or ON ERROR SKIP [nn] or ON ERROR CLEAR	<p>This controls the action taken if an error occurs while running a program and applies to all errors discovered by MMBasic including syntax errors, wrong data, missing hardware, etc.</p> <p>ON ERROR ABORT will cause MMBasic to display an error message, abort the program and return to the command prompt. This is the normal behaviour of MMBasic and is the default when a program starts running.</p> <p>ON ERROR IGNORE will cause any error to be ignored.</p> <p>ON ERROR SKIP will ignore an error in a number of commands (specified by the number 'nn') executed following this command. 'nn' is optional, the default if not specified is one. After the number of commands has completed (with an error or not) the behaviour of MMBasic will revert to ON ERROR ABORT.</p> <p>If an error occurs and is ignored/skipped the read only variable MM.ERRNO will be set to non zero and MM.ERRMSG\$ will be set to the error message that would normally be generated. These are reset to zero and an empty string by ON ERROR CLEAR. They are also cleared when the program is run and when ON ERROR IGNORE and ON ERROR SKIP are used.</p> <p>ON ERROR IGNORE can make it very difficult to debug a program so it is strongly recommended that only ON ERROR SKIP be used.</p>
ON nbr GOTO GOSUB target[,target, target,...]	ON either branches (GOTO) or calls a subroutine (GOSUB) based on the rounded value of 'nbr'; if it is 1, the first target is called, if 2, the second target is called, etc. Target can be a line number or a label.
ON KEY target	<p>Setup an interrupt which will call 'target' user defined subroutine whenever there is one or more characters waiting in the serial console input buffer.</p> <p>Note that all characters waiting in the input buffer should be read in the interrupt subroutine otherwise another interrupt will be automatically generated as soon as the program returns from the interrupt.</p> <p>To disable this interrupt, use numeric zero for the target, ie: ON KEY 0</p>
OPEN comspec\$ AS [#]fnbr	<p>Will open a serial communications port for reading and writing. Two ports are available (COM1: and COM2:) and both can be open simultaneously. For a full description with examples see Appendix A.</p> <p>Using 'fnbr' the port can be written to and read from using any command or function that uses a file number.</p>
OPTION AUTORUN OFF ON	<p>Instruct MMBasic to automatically run the program stored in flash when it starts up or is restarted by the WATCHDOG command. This is turned off by the NEW command but other commands that might change program memory (EDIT, etc) do not change this setting.</p> <p>Entering the break key (default CTRL-C) at the console will interrupt the running program and return to the command prompt.</p>
OPTION BASE 0 1	<p>Set the lowest value for array subscripts to either 0 or 1.</p> <p>This must be used before any arrays are declared and is reset to the default of 0 on power up.</p>

OPTION BAUDRATE nbr	<p>Set the baud rate for the console to 'nbr'. This change is made immediately and will be remembered even when the power is cycled. The baud rate should be limited to the speeds listed in Appendix A for COM1.</p> <p>Using this command it is possible to set the console to an unworkable baud rate and in this case MMBasic should be reset as described in the chapter "Resetting MMBasic". This will reset the baud rate to the default of 38400.</p>
OPTION BREAK nn	<p>Set the value of the break key to the ASCII value 'nn'. This key is used to interrupt a running program.</p> <p>The value of the break key is set to CTRL-C key at power up but it can be changed to any keyboard key using this command (for example, OPTION BREAK 4 will set the break key to the CTRL-D key).</p> <p>Setting this option to zero will disable the break function entirely.</p>
OPTION CASE UPPER LOWER TITLE	<p>Change the case used for listing command and function names when using the LIST command. The default is TITLE but the old standard of MMBasic can be restored using OPTION CASE UPPER.</p> <p>This option will be remembered even when the power is removed.</p>
OPTION CLOCKTRIM ±n	<p>Trim the frequency of the internal oscillator on the 28 and 44-pin Micromites. This oscillator is used as the basis for all timing (eg, date, time, pause, PWM frequency, serial baudrate, etc).</p> <p>'n' is the trim value which can range from -31 to +31 (this equates to an adjustment range of about -12.5% to +12.5%). On power up the trim value is zero.</p> <p>Note that this will also affect the console baudrate and an excessive trim value could make it impossible to communicate with the Micromite.</p>
OPTION COLOURCODE ON or OPTION COLOURCODE OFF	<p>Turn on or off colour coding for the editor's output. Keywords will be in cyan, numbers in red, etc. The default is off.</p> <p>Notes:</p> <ul style="list-style-type: none"> • This setting is saved in flash memory and is applied on startup. • Colour coding requires a terminal emulator that can interpret the appropriate escape codes. It works correctly with Tera Term however Putty needs its default background colour to be changed to white. • If colour coding is used it is recommended that the baud rate for the serial console be set to a high speed. • The keyword COLORCODE (USA spelling) can also be used.
OPTION CONSOLE ECHO or OPTION CONSOLE NOECHO or OPTION CONSOLE INVERT or OPTION CONSOLE NOINVERT or OPTION CONSOLE AUTO	<p>Used to set options for the console serial port.</p> <p>NOECHO will turn off the echoing of characters received at the console. ECHO will re enable the echo. The default is ECHO at bootup and the option is reset to ECHO whenever the program returns to the command prompt. This option is useful when the console is used as a third general purpose serial port.</p> <p>INVERT will invert the data polarity on both the console transmit and receive lines. This allows the console to be used with RS232 signals without a converter (see the chapter "Low Cost RS-232 Interface" in Appendix A). It also allows the use of a PICAXE style programming cable.</p> <p>NOINVERT will restore the console to its normal operation and is the default.</p> <p>AUTO will automatically invert the data polarity on the console depending on the signal level at power up (a low input means that the console will be inverted). This will automatically switch between TTL serial and RS232 serial input. Note that there is a 200ms startup delay when AUTO is used.</p> <p>This option will be remembered even when the power is removed.</p>

OPTION DEFAULT FLOAT INTEGER STRING NONE	<p>Used to set the default type for a variable which is not explicitly defined.</p> <p>If OPTION DEFAULT NONE is used then all variables must have their type explicitly defined.</p> <p>When a program is run the default is set to FLOAT for compatibility with previous versions of MMBasic.</p>
OPTION DISPLAY lines [,chars]	<p>Set the characteristics of the display terminal used for the console. Both the LIST and EDIT commands need to know this information to correctly format the text for display.</p> <p>'lines' is the number of lines on the display and 'chars' is the width of the display in characters. The default is 24 lines x 80 chars and when changed this option will be remembered even when the power is removed.</p> <p>Note that the documentation for the VT100 ASCII Video Terminal initially listed incorrect specifications for the composite video. If you are using this project with the Micromite check the website http://geoffg.net/terminal.html for the correct specifications.</p>
OPTION EXPLICIT	<p>Placing this command at the start of a program will require that every variable be explicitly declared using the DIM command before it can be used in the program.</p> <p>This option is disabled by default when a program is run. If it is used it must be specified before any variables are used.</p>
OPTION LCDPANEL ILI9341, orientation, D/C pin, reset pin [,CS pin] or OPTION LCDPANEL DISABLE	<p>Configures the Micromite and Micromite Plus to work with an attached LCD panel using the ILI9341 controller.</p> <p>'orientation' can be LANDSCAPE, PORTRAIT, RLANDSCAPE or RPORTRAIT. These can be abbreviated to L, P, RL or RP. The R prefix indicates the reverse or "upside down" orientation.</p> <p>'C/D pin' and 'reset pin' are the Micromite I/O pins to be used for these functions. Any free pin can be used. 'CS pin' can also be any I/O pin but is optional. If a touch controller is not used this parameter can be left off the command and the CS pin on the LCD display wired permanently to ground. If the touch controller is used this pin must then be specified and connected to a Micromite I/O pin.</p> <p>NOTE: The CPU speed must be 20 MHz or greater.</p>
OPTION LIST	<p>This will list the settings of any options that have been changed from their default setting and are the type that is saved in flash. This command is useful when configuring options that reserve I/O pins (ie, OPTION LCDPANEL or OPTION TOUCH) and you need to know what pins are in use.</p>
OPTION PIN nbr	<p>Set 'nbr' as the PIN (Personal Identification Number) for access to the console prompt. 'nbr' can be any non zero number of up to eight digits.</p> <p>Whenever a running program tries to exit to the command prompt for whatever reason MMBasic will request this number before the prompt is presented. This is a security feature as without access to the command prompt an intruder cannot list or change the program in memory or modify the operation of MMBasic in any way. To disable this feature enter zero for the PIN number (ie, OPTION PIN 0).</p> <p>A permanent lock can be applied by using 99999999 for the PIN number.</p> <p>If a permanent lock is applied or the PIN number is lost the only way to recover is to reset MMBasic as described in the chapter "Resetting MMBasic" (this will also erase the program memory).</p>
OPTION RESET	<p>Reset all saved options (including the PIN) to the default values.</p>
OPTION TAB 2 4 8	<p>Set the spacing for the tab key. Default is 2.</p> <p>This option will be remembered even when the power is removed.</p>

OPTION TOUCH T_CS pin, T_IRQ pin or OPTION TOUCH DISABLE	Configures MMBasic for the touch sensitive feature of an attached LCD panel. 'T_CS pin' and 'T_IRQ pin' are the Micromite I/O pins to be used for chip select and touch interrupt respectively (any free pins can be used).
PAUSE delay	Halt execution of the running program for 'delay' ms. This can be a fraction. For example, 0.2 is equal to 200 µs. The maximum delay is 2147483647 ms (about 24 days). Note that interrupts will be recognised and processed during a pause.
PIN(pin) = value	For a 'pin' configured as digital output this will set the output to low ('value' is zero) or high ('value' non-zero). You can set an output high or low before it is configured as an output and that setting will be the default output when the SETPIN command takes effect. See the function PIN() for reading from a pin and the command SETPIN for configuring it. Refer to the chapter <i>"Using the I/O pins"</i> for a general description of the Micromite's input/output capabilities.
PIXEL x, y [,c]	Set a pixel on an attached LCD panel to a colour. 'x' is the horizontal coordinate and 'y' is the vertical coordinate of the pixel. 'c' is a 24 bit number specifying the colour. 'c' is optional and if omitted the current foreground colour will be used. See the chapter <i>"Basic Drawing Commands"</i> for a definition of the colours and graphics coordinates.
POKE BYTE addr%, byte or POKE WORD addr%, word% or POKE VAR var, offset, byte or POKE VARTBL, offset, byte	Will set a byte or a word within the PIC32 virtual memory space. POKE BYTE will set the byte (ie, 8 bits) at the memory location 'addr%' to 'byte'. 'addr%' should be an integer. POKE WORD will set the word (ie, 32 bits) at the memory location 'addr%' to 'word%'. 'addr%' and 'word%' should be integers. POKE VAR will set a byte in the memory address of 'var'. 'offset' is the ±offset from the address of the variable. An array is specified as var(). POKE VARTBL will set a byte in MMBasic's variable table. 'offset' is the ±offset from the start of the variable table. Note that a comma is required after the keyword VARTBL. For backwards compatibility the old form of POKE hiword, loword, val is still accepted. In this case the address is specified by 'hiword' which is the top 16 bits of the address while 'loword' is the bottom 16 bits. This command is for expert users only. The PIC32 maps all control registers, flash (program) memory and volatile (RAM) memory into a single address space so there is no need for INP or OUT commands. The PIC32 Data Sheet lists the details of this address space (RAM starts at 0xA0000000).
PORT(start, nbr [,start, nbr]...) = value	Set a number of I/O pins simultaneously (ie, with one command). 'start' is an I/O pin number and the lowest bit in 'value' (bit 0) will be used to set that pin. Bit 1 will be used to set the pin 'start' plus 1, bit 2 will set pin 'start'+2 and so on for 'nbr' number of bits. I/O pins used must be numbered consecutively and any I/O pin that is invalid or not configured as an output will cause an error. The start/nbr pair can be repeated if an additional group of output pins needed to be added. For example; PORT(15, 4, 23, 4) = &B10000011 Will set eight I/O pins. Pins 15 and 16 will be set high while 17, 18, 23, 24 and 25 will be set to a low and finally 26 will be set high. This command can be used to conveniently communicate with parallel devices like LCD displays. Any number of I/O pins (and therefore bits) can be used from 1 to the number of I/O pins on the chip. See the PORT function to simultaneously read from a number of pins.

<p>PRINT expression [[,;]expression] ... etc</p>	<p>Outputs text to the serial console. Multiple expressions can be used and must be separated by either a:</p> <ul style="list-style-type: none"> • Comma (,) which will output the tab character • Semicolon (;) which will not output anything (it is just used to separate expressions). • Nothing or a space which will act the same as a semicolon. <p>A semicolon (;) at the end of the expression list will suppress the automatic output of a carriage return/ newline at the end of a print statement.</p> <p>When printed, a number is preceded with a space if positive or a minus (-) if negative but is not followed by a space. Integers (whole numbers) are printed without a decimal point while fractions are printed with the decimal point and the significant decimal digits. Large floating point numbers (greater than six digits) are printed in scientific number format.</p> <p>The function TAB() can be used to space to a certain column and the string functions can be used to justify or otherwise format strings.</p>
<p>PRINT #nbr, expression [[,;]expression] ... etc</p>	<p>Same as above except that the output is directed to a serial communications port previously opened as 'nbr'. See the OPEN command.</p>
<p>PULSE pin, width</p>	<p>Will generate a pulse on 'pin' with duration of 'width' ms. 'width' can be a fraction. For example, 0.01 is equal to 10µs and this enables the generation of very narrow pulses. The minimum is 5 µs at 40 MHz to 40 µs at 5 MHz.</p> <p>The generated pulse is of the opposite polarity to the state of the I/O pin when the command is executed. For example, if the output is set high the PULSE command will generate a negative going pulse. Notes:</p> <ul style="list-style-type: none"> • 'pin' must be configured as an output. • For a pulse of less than 3 ms the accuracy is $\pm 1 \mu s$. • For a pulse of 3 ms or more the accuracy is $\pm 0.5 ms$. • A pulse of 3 ms or more will run in the background. Up to five different and concurrent pulses can be running in the background and each can have its time changed by issuing a new PULSE command or it can be terminated by issuing a PULSE command with zero for 'width'.
<p>PWM 1, freq, 1A or PWM 1, freq, 1A, 1B or PWM 1, freq, 1A, 1B, 1C or PWM 2, freq, 2A or PWM 2, freq, 2A, 2B or PWM channel, STOP</p>	<p>Generate a pulse width modulated (PWM) output for driving analogue circuits, sound output, etc.</p> <p>There are a total of five outputs designated as PWM in the diagrams on pages 6 and 7 (they are also used for the SERVO command). Controller 1 can have one, two or three outputs while controller 2 can have one or two outputs. Both controllers are independent and can be turned on and off and have different frequencies.</p> <p>'1' or '2' is the controller number and 'freq' is the output frequency (between 20Hz and 500kHz). 1A, 1B and 1C are the duty cycle for each of the controller 1 outputs while 2A and 2B are the duty cycle for the controller 2 outputs. The specified I/O pins will be automatically configured as outputs while any others will be unaffected and can be used for other duties.</p> <p>The duty cycle for each output is independent of the others and is specified as a percentage. If it is close to zero the output will be a narrow positive pulse, if 50 a square wave will be generated and if close to 100 it will be a very wide positive pulse. For frequencies below 25 kHz the duty cycle will be accurate to 0.1%.</p> <p>The output will run continuously in the background while the program is running and can be stopped using the STOP command. The frequency and duty cycle can be changed at any time (without stopping the output) by issuing a new PWM command.</p> <p>The PWM function will take control of any specified outputs and when stopped the pins will be returned to a high impedance "not configured" state.</p>

RANDOMIZE nbr	Seed the random number generator with 'nbr'. On power up the random number generator is seeded with zero and will generate the same sequence of random numbers each time. To generate a different random sequence each time you must use a different value for 'nbr' (the TIMER function is handy for that).
RBOX x, y, w, h [, r] [,c] [,fill]	Draws a box with rounded corners on an attached LCD panel starting at 'x' and 'y' which is 'w' pixels wide and 'h' pixels high. 'r' is the radius of the corners of the box. It defaults to 10. 'c' specifies the colour and defaults to the default foreground colour if not specified. 'fill' is the fill colour. It can be omitted or set to -1 in which case the box will not be filled. See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.
READ variable[, variable]...	Reads values from DATA statements and assigns these values to the named variables. Variable types in a READ statement must match the data types in DATA statements as they are read. See also DATA and RESTORE.
REM string	REM allows remarks to be included in a program. Note the Microsoft style use of the single quotation mark to denote remarks is also supported and is preferred.
RESTORE [line]	Resets the line and position counters for the READ statement. If 'line' is specified the counters will be reset to the beginning of the specified line. 'line' can be a line number or label. If 'line' is not specified the counters will be reset to the start of the program.
RETURN	RETURN concludes a subroutine called by GOSUB and returns to the statement after the GOSUB.
RTC GETTIME or RTC SETTIME year, month, day, hour, minute, second or RTC SETREG reg, value or RTC GETREG reg, var	RTC GETTIME will get the current date/time from a PCF8563, DS1307, DS3231 or DS3232 real time clock and set the internal MMBasic clock accordingly. The date/time can then be retrieved with the DATE\$ and TIME\$ functions. RTC SETTIME will set the time in the clock chip. 'hour' must use 24 hour notation. The RTC SETREG and GETREG commands can be used to set or read the contents of registers within the chip. 'reg' is the register's number, 'value' is the number to store in the register and 'var' is a variable that will receive the number read from the register. These commands are not necessary for normal operation but they can be used to manipulate special features of the chip (alarms, output signals, etc). They are also useful for storing temporary information in the chip's battery backed RAM. These chips are I ² C devices and must be connected to the two I ² C pins with appropriate pullup resistors. If the I ² C bus is already open the RTC command will use the current settings, otherwise it will temporarily open the connection with a speed of 100 kHz. See the chapter "Special Hardware Devices" for more details.
RUN	Run the program held in flash memory. On the Micromite Plus <i>RUN file\$</i> can be used and this will load and run a file residing on the SD card.

<pre> SELECT CASE value CASE testexp [[, testexp] ...] <statements> <statements> CASE ELSE <statements> <statements> END SELECT </pre>	<p>Executes one of several groups of statements, depending on the value of an expression. 'value' is the expression to be tested. It can be a number or string variable or a complex expression. 'testexp' is the value that 'exp' is to be compared against. It can be:</p> <ul style="list-style-type: none"> • A single expression (ie, 34, "string" or PIN(4)*5) to which it may equal • A range of values in the form of two single expressions separated by the keyword "TO" (ie, 5 TO 9 or "aa" TO "cc") • A comparison starting with the keyword "IS" (which is optional). For example: IS > 5, IS <= 10. <p>When a number of test expressions (separated by commas) are used the CASE statement will be true if any one of these tests evaluates to true.</p> <p>If 'value' cannot be matched with a 'testexp' it will be automatically matched to the CASE ELSE. If CASE ELSE is not present the program will not execute any <statements> and continue with the code following the END SELECT.</p> <p>When a match is made the <statements> following the CASE statement will be executed until END SELECT or another CASE is encountered when the program will then continue with the code following the END SELECT.</p> <p>An unlimited number of CASE statements can be used but there must be only one CASE ELSE and that should be the last before the END SELECT.</p> <p>Example:</p> <pre> SELECT CASE nbr% CASE 4, 9, 22, 33 TO 88 statements CASE IS < 4, IS > 88, 5 TO 8 statements CASE ELSE statements END SELECT </pre> <p>Each SELECT CASE must have one and one only matching END SELECT statement. Any number of SELECT...CASE statements can be nested inside the CASE statements of other SELECT...CASE statements.</p>
<pre> SERVO 1 [, freq], 1A or SERVO 1 [, freq], 1A, 1B or SERVO 1 [, freq], 1A, 1B, 1C or SERVO 2 [, freq], 2A or SERVO 2 [, freq], 2A, 2B or SERVO channel, STOP </pre>	<p>Generate a constant stream of positive going pulses for driving a servo.</p> <p>The Micromite has two servo controllers with the first being able to control up to three servos and the second two servos. Both controllers are independent and can be turned on and off and have different frequencies. This command uses the I/O pins that are designated as PWM in the diagrams on pages 6 and 7 (the two commands are very similar).</p> <p>'1' or '2' is the controller number. 'freq' is the output frequency (between 20Hz and 1000 Hz) and is optional. If not specified it will default to 50 Hz</p> <p>1A, 1B and 1C are the pulse widths for each of the controller 1 outputs while 2A and 2B are the pulse widths for the controller 2 outputs. The specified I/O pins will be automatically configured as outputs while any others will be unaffected and can be used for other duties.</p> <p>The pulse width for each output is independent of the others and is specified in milliseconds, which can be a fractional number (ie, 1.536). For accurate positioning the output resolution is about 0.005 ms. The minimum value is 0.01ms while the maximum is 18.9ms. Most servos will accept a range of 0.8ms to 2.2ms.</p> <p>The output will run continuously in the background while the program is running and can be stopped using the STOP command. The pulse widths of the outputs can be changed at any time (without stopping the output) by issuing a new SERVO command.</p> <p>The SERVO function will take control of any specified outputs and when stopped the pins will be returned to a high impedance "not configured" state. See the chapter "Special Hardware Devices" for more details.</p>

SETPIN pin, cfg [, option]	<p>Will configure an external I/O pin. Refer to the chapter <i>"Using the I/O pins"</i> for a general description of the Micromite's input/output capabilities.</p> <p>'pin' is the I/O pin to configure, 'cfg' is the mode that the pin is to be set to and 'option' is an optional parameter. 'cfg' is a keyword and can be any one of the following:</p> <ul style="list-style-type: none"> OFF Not configured or inactive AIN Analog input (ie, measure the voltage on the input) DIN Digital input If 'option' is omitted the input will be high impedance If 'option' is the keyword "PULLUP" an internal resistor will be used to pull up the input pin to 3.3V If the keyword "PULLDOWN" is used the pin will be pulled down to zero volts. The value of the pull up or down is the equivalent of about 100K. FIN Frequency input 'option' can be used to specify the gate time (the length of time used to count the input cycles). It can be any number between 10 ms and 100000 ms. Note that the PIN() function will always return the frequency correctly scaled in Hz regardless of the gate time used. If 'option' is omitted the gate time will be 1 second. PIN Period input 'option' can be used to specify the number of input cycles to average the period measurement over. It can be any number between 1 and 10000. Note that the PIN() function will always return the average period of one cycle correctly scaled in ms regardless of the number of cycles used for the average. If 'option' is omitted the period of just one cycle will be used. CIN Counting input DOUT Digital output 'option' can be "OC" in which case the output will be open collector (or more correctly open drain). The functions PIN() and PORT() can also be used to return the value on one or more output pins . <p>Previous versions of MMBasic used numbers for 'cfg' and the mode OOUT. For backwards compatibility they will still be recognised.</p> <p>See the function PIN() for reading inputs and the statement PIN()= for setting an output. See the command below if an interrupt is configured.</p>
SETPIN pin, cfg, target [, option]	<p>Will configure 'pin' to generate an interrupt according to 'cfg'. Any I/O pin capable of digital input can be configured to generate an interrupt with a maximum of ten interrupts configured at any one time.</p> <p>'cfg' is a keyword and can be any one of the following:</p> <ul style="list-style-type: none"> OFF Not configured or inactive INTH Interrupt on low to high input INTL Interrupt on high to low input INTB Interrupt on both (ie, any change to the input) <p>'target' is a user defined subroutine which will be called when the event happens. Return from the interrupt is via the END SUB or EXIT SUB commands. If 'option' is the keyword "PULLUP" an internal resistor will be used to pull up the input pin to 3.3V If the keyword "PULLDOWN" is used the pin will be pulled down to zero volts. The pull up or down is about 100K. If 'option' is omitted the input will be high impedance.</p> <p>This mode also configures the pin as a digital input so the value of the pin can always be retrieved using the function PIN().</p> <p>Refer to the chapter <i>"Using the I/O pins"</i> for a general description of the Micromite's input/output capabilities.</p>

SETTICK period, target [, nbr]	<p>This will setup a periodic interrupt (or "tick").</p> <p>Four tick timers are available ('nbr' = 1, 2, 3 or 4). 'nbr' is optional and if not specified timer number 1 will be used.</p> <p>The time between interrupts is 'period' milliseconds and 'target' is the interrupt subroutine which will be called when the timed event occurs.</p> <p>The period can range from 1 to 2147483647 ms (about 24 days).</p> <p>These interrupts can be disabled by setting 'period' to zero (ie, SETTICK 0, 0, 3 will disable tick timer number 3).</p>
STATIC variable [, variables] See DIM for the full syntax.	<p>Defines a list of variable names which are local to the subroutine or function. These variables will retain their value between calls to the subroutine or function (unlike variables created using the LOCAL command).</p> <p>This command uses exactly the same syntax as DIM. The only difference is that the length of the variable name created by STATIC and the length of the subroutine or function name added together cannot exceed 32 characters.</p> <p>Static variables can be initialised to a value. This initialisation will take effect only on the first call to the subroutine (not on subsequent calls).</p>
SUB xxx (arg1 [,arg2, ...]) <statements> <statements> END SUB	<p>Defines a callable subroutine. This is the same as adding a new command to MMBasic while it is running your program.</p> <p>'xxx' is the subroutine name and it must meet the specifications for naming a variable.</p> <p>'arg1', 'arg2', etc are the arguments or parameters to the subroutine. An array is specified by using empty brackets. ie, arg3(). The type of the argument can be specified by using a type suffix (ie, arg1\$) or by specifying the type using AS <type> (ie, arg1 AS STRING).</p> <p>Every definition must have one END SUB statement. When this is reached the program will return to the next statement after the call to the subroutine. The command EXIT SUB can be used for an early exit.</p> <p>You use the subroutine by using its name and arguments in a program just as you would a normal command. For example: MySub a1, a2</p> <p>When the subroutine is called each argument in the caller is matched to the argument in the subroutine definition. These arguments are available only inside the subroutine. Subroutines can be called with a variable number of arguments. Any omitted arguments in the subroutine's list will be set to zero or a null string.</p> <p>Arguments in the caller's list that are a variable (ie, not an expression or constant) will be passed by reference to the subroutine. This means that any changes to the corresponding argument in the subroutine will also be copied to the caller's variable and therefore may be accessed after the subroutine has ended. Arrays are passed by specifying the array name with empty brackets (eg, arg()) and are always passed by reference. Brackets around the argument list in both the caller and the definition are optional.</p>
TEMPR START pin [, precision]	<p>This command can be used to start a conversion running on a DS18B20 temperature sensor connected to 'pin'.</p> <p>Normally the TEMPR() function alone is sufficient to make a temperature measurement so usage of this command is optional and can be ignored.</p> <p>This command will start the measurement on the temperature sensor. The program can then attend to other duties while the measurement is running and later use the TEMPR() function to get the reading. If the TEMPR() function is used before the conversion time has completed the function will wait for the remaining conversion time before returning the value.</p> <p>Any number of these conversions (on different pins) can be started and be running simultaneously.</p> <p>'precision' is the resolution of the measurement and is optional. It is a number between 0 and 3 meaning:</p>

	<p>0 = 0.5°C resolution, 100 ms conversion time.</p> <p>1 = 0.25°C resolution, 200 ms conversion time (this is the default).</p> <p>2 = 0.125°C resolution, 400 ms conversion time.</p> <p>3 = 0.0625°C resolution, 800 ms conversion time.</p>
<p>TEXT x, y, string\$</p> <p>[,alignment\$] [, font] [, scale]</p> <p>[, c] [, bc]</p>	<p>Displays a string on an attached LCD panel starting at 'x' and 'y'.</p> <p>'string\$' is the string to be displayed. Note that numeric data can be converted to a string and formatted using the Str\$() function.</p> <p>'alignment\$' is a string expression or string variable consisting of 0, 1 or 2 letters where the first letter is the horizontal alignment around 'x' and can be L, C or R for LEFT, CENTER, RIGHT and the second letter is the vertical alignment around 'y' and can be T, M or B for TOP, MIDDLE, BOTTOM. The default alignment is left/top.</p> <p>In the Micromite Plus a third letter can be used in the alignment string to indicate the rotation of the text. This can be 'N' for normal orientation, 'V' for vertical text with each character under the previous running from top to bottom, 'I' the text will be inverted (ie, upside down), 'U' the text will be rotated counter clockwise by 90° and 'D' the text will be rotated clockwise by 90°.</p> <p>'font' and 'scale' are optional and default to that set by the FONT command.</p> <p>'c' is the drawing colour and 'bc' is the background colour. They are optional and default to the current foreground and background colours.</p> <p>See the chapter "Basic Drawing Commands" for a definition of the colours and graphics coordinates.</p>
<p>TIME\$ = "HH:MM:SS"</p> <p>or</p> <p>TIME\$ = "HH:MM"</p> <p>or</p> <p>TIME\$ = "HH"</p>	<p>Sets the time of the internal clock. MM and SS are optional and will default to zero if not specified. For example TIME\$ = "14:30" will set the clock to 14:30 with zero seconds.</p> <p>The time is set to "00:00:00" on power up.</p>
<p>TIMER = msec</p>	<p>Resets the timer to a number of milliseconds. Normally this is just used to reset the timer to zero but you can set it to any positive integer.</p> <p>See the TIMER function for more details.</p>
<p>TRACE ON</p> <p>or</p> <p>TRACE OFF</p> <p>or</p> <p>TRACE LIST nn</p>	<p>TRACE ON/OFF will turn on/off the trace facility. This facility will print the number of each line (counting from the beginning of the program) in square brackets as the program is executed. This is useful in debugging programs.</p> <p>Micromite Plus only: TRACE LIST will list the last 'nn' lines executed in the format described above. Note that MMBasic is always logging the lines executed so this facility is always available (ie, it does not have to be turned on).</p>
<p>VAR SAVE var [, var]...</p> <p>or</p> <p>VAR RESTORE</p> <p>or</p> <p>VAR CLEAR</p>	<p>VAR SAVE will save one or more variables to non volatile flash memory where they can be restored later (normally after a power interruption).</p> <p>'var' can be any number of numeric or a string variables and/or arrays. Arrays are specified by using empty brackets. For example: var()</p> <p>VAR RESTORE will retrieve the previously saved variables and insert them (and their values) into the variable table.</p> <p>The VAR SAVE command can be used repeatedly. Variables that had been previously saved will be updated with their new value and any new variables (not previously saved) will be added to the saved list for later restoration.</p> <p>VAR CLEAR will erase all saved variables. Also, the saved variables will be automatically cleared by the NEW command or when a new program is loaded.</p> <p>This command is normally used to save calibration data, options, and other</p>

	<p>data which does not change often but needs to be retained across a power interruption. Normally the VAR RESTORE command is placed at the start of the program so that previously saved variables are restored and immediately available to the program when it starts.</p> <p>Notes:</p> <ul style="list-style-type: none"> • The storage space available to this command is 2KB on the standard 28 and 44 pin Micromites or 4KB on the Micromite Plus. • Using VAR RESTORE without a previous save will have no effect and will not generate an error. • If, when using RESTORE, a variable with the same name already exists its value will be overwritten. • Saved arrays must be declared (using DIM) before they can be restored. • Be aware that string arrays can rapidly use up all the memory allocated to this command. The LENGTH qualifier can be used when a string array is declared to reduce the size of the array (see the DIM command).
WATCHDOG timeout or WATCHDOG OFF	<p>Starts the watchdog timer which will automatically restart the processor when it has timed out. This can be used to recover from some event that disabled the running program (such as an endless loop or a programming or other error that halts a running program). This can be important in an unattended control situation.</p> <p>'timeout' is the time in milliseconds (ms) before a restart is forced. This command should be placed in strategic locations in the running BASIC program to constantly reset the watchdog timer and therefore prevent it from counting down to zero.</p> <p>If the timer count does reach zero (perhaps because the BASIC program has stopped running) the Micromite will be automatically restarted and the automatic variable MM.WATCHDOG will be set to true (ie, 1) indicating that an error occurred. On a normal startup MM.WATCHDOG will be set to false (ie, 0).</p> <p>At any time WATCHDOG OFF can be used to disable the watchdog timer (this is the default on a reset or power up). The timer is also turned off when the break character (normally CTRL-C) is used on the console to interrupt a running program.</p>
XMODEM SEND or XMODEM RECEIVE Micromite Plus only: XMODEM SEND file\$ or XMODEM RECEIVE file\$	<p>Transfers a BASIC program to or from a remote computer using the XModem protocol. The transfer is done over the serial console connection. XMODEM SEND will send the current program held in the Micromite's program memory to the remote device.</p> <p>XMODEM RECEIVE will accept a program sent by the remote device and save it into the Micromite's program memory overwriting the program currently held there. Note that the data is buffered in RAM which limits the maximum program size.</p> <p>SEND and RECEIVE can be abbreviated to S and R.</p> <p>With the Micromite Plus you can also specify 'file\$' which will transfer the data to/from a file on the SD card. If the file already exists it will be overwritten when receiving a file.</p> <p>The XModem protocol requires a cooperating software program running on the remote computer and connected to its serial port. It has been tested on Tera Term running on Windows and it is recommended that this be used. After running the XMODEM command in MMBasic select:</p> <p style="padding-left: 40px;">File -> Transfer -> XMODEM -> Receive/Send</p> <p>from the Tera Term menu to start the transfer.</p> <p>The transfer can take up to 15 seconds to start and if the XMODEM command fails to establish communications it will return to the MMBasic</p>

	prompt after 60 seconds and leave the program memory untouched. Download Tera Term from http://ttssh2.sourceforge.jp/
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Functions

Note that the functions related to communications functions (I²C, 1-Wire, and SPI) are not listed here but are described in the appendices at the end of this document.

Square brackets indicate that the parameter or characters are optional.

ACOS(number)	Returns the inverse cosine of the argument 'number' in radians.
ABS(number)	Returns the absolute value of the argument 'number' (ie, any negative sign is removed and the positive number is returned).
ASC(string\$)	Returns the ASCII code for the first letter in the argument 'string\$'.
ASIN(number)	Returns the inverse sine value of the argument 'number' in radians.
ATN(number)	Returns the arctangent of the argument 'number' in radians.
BIN\$(number [, chars])	Returns a string giving the binary (base 2) value for the 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).
CHR\$(number)	Returns a one-character string consisting of the character corresponding to the ASCII code indicated by argument 'number'.
CINT(number)	Round numbers with fractional portions up or down to the next whole number or integer. For example, 45.47 will round to 45 45.57 will round to 46 -34.45 will round to -34 -34.55 will round to -35 See also INT() and FIX().
COS(number)	Returns the cosine of the argument 'number' in radians.
DATE\$	Returns the current date based on MMBasic's internal clock as a string in the form "DD-MM-YYYY". For example, "28-07-2012". The internal clock/calendar will keep track of the time and date including leap years. To set the date use the command DATE\$ =.
DEG(radians)	Converts 'radians' to degrees.
EOF([#]nbr)	For a serial communications port this function will return true if there are no characters waiting in the receive buffer. #0 can be used which refers to the console's input buffer. The # is optional. Also see the OPEN, INPUT and LINE INPUT commands and the INPUT\$ function.
EXP(number)	Returns the exponential value of 'number'.

FIX(number)	<p>Truncate a number to a whole number by eliminating the decimal point and all characters to the right of the decimal point.</p> <p>For example 9.89 will return 9 and -2.11 will return -2.</p> <p>The major difference between FIX and INT is that FIX provides a true integer function (ie, does not return the next lower number for negative numbers as INT() does). This behaviour is for Microsoft compatibility. See also CINT() .</p>
HEX\$(number [, chars])	<p>Returns a string giving the hexadecimal (base 16) value for the 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).</p>
INKEY\$	<p>Checks the console input buffer and, if there is one or more characters waiting in the queue, will remove the first character and return it as a single character in a string.</p> <p>If the input buffer is empty this function will immediately return with an empty string (ie, "").</p>
INPUT\$(nbr, [#]fnbr)	<p>Will return a string composed of 'nbr' characters read from a serial communications port opened as 'fnbr'. This function will return as many characters as are waiting in the receive buffer up to 'nbr'. If there are no characters waiting it will immediately return with an empty string.</p> <p>#0 can be used which refers to the console's input buffer.</p> <p>The # is optional. Also see the OPEN command.</p>
INSTR([start-position,] string-searched\$, string-pattern\$)	<p>Returns the position at which 'string-pattern\$' occurs in 'string-searched\$', beginning at 'start-position'.</p> <p>Both the position returned and 'start-position' use 1 for the first character, 2 for the second, etc. The function returns zero if 'string-pattern\$' is not found.</p>
INT(number)	<p>Truncate an expression to the next whole number less than or equal to the argument. For example 9.89 will return 9 and -2.11 will return -3.</p> <p>This behaviour is for Microsoft compatibility, the FIX() function provides a true integer function.</p> <p>See also CINT() .</p>
LEFT\$(string\$, nbr)	<p>Returns a substring of 'string\$' with 'nbr' of characters from the left (beginning) of the string.</p>
LEN(string\$)	<p>Returns the number of characters in 'string\$'.</p>
LOC([#]fnbr)	<p>For a serial communications port opened as 'fnbr' this function will return the number of bytes received and waiting in the receive buffer to be read.</p> <p>#0 can be used which refers to the console's input buffer.</p> <p>The # is optional.</p>
LOF([#]fnbr)	<p>For a serial communications port opened as 'fnbr' this function will return the space (in characters) remaining in the transmit buffer. Note that when the buffer is full MMBasic will pause when adding a new character and wait for some space to become available.</p> <p>The # is optional.</p>

LOG(number)	Returns the natural logarithm of the argument 'number'.
LCASE\$(string\$)	Returns 'string\$' converted to lowercase characters.
MAX(arg1 [, arg2 [, ...]]) or MIN(arg1 [, arg2 [, ...]])	Returns the maximum or minimum number in the argument list. Note that the comparison is a floating point comparison (integer arguments are converted to floats) and a float is returned.
MID\$(string\$, start) or MID\$(string\$, start, nbr)	Returns a substring of 'string\$' beginning at 'start' and continuing for 'nbr' characters. The first character in the string is number 1. If 'nbr' is omitted the returned string will extend to the end of 'string\$'
OCT\$(number [, chars])	Returns a string giving the octal (base 8) representation of 'number'. 'chars' is optional and specifies the number of characters in the string with zero as the leading padding character(s).
PEEK(BYTE addr%) or PEEK(WORD addr%) or PEEK(VARADDR var) or PEEK(CFUNADDR cfun) or PEEK(VAR var, ±offset) or PEEK(VARTBL, ±offset) or PEEK(PROGMEM, ±offset)	Will return a byte or a word within the PIC32 virtual memory space. BYTE will return the byte (8-bits) located at 'addr%' WORD will return the word (32-bits) located at 'addr%' VARADDR will return the address (32-bits) of the variable 'var' in memory. An array is specified as var(). CFUNADDR will return the address (32-bits) of the CFunction 'cfun' in memory. This address can be passed to another CFunction which can then call it to perform some common process. VAR, will return a byte in the memory allocated to 'var'. An array is specified as var(). VARTBL, will return a byte in the memory allocated to the variable table maintained by MMBasic. Note that there is a comma after the keyword VARTBL. PROGMEM, will return a byte in the memory allocated to the program. Note that there is a comma after the keyword PROGMEM. Note that 'addr%' should be an integer. For backwards compatibility PEEK(hiword, loword) is still accepted. In this case the address is specifies by 'hiword' which is the top 16 bits of the address while 'loword' is the bottom 16 bits. This command is for expert users only. The PIC32 maps all control registers, flash (program) memory and volatile (RAM) memory into a single address space so there is no need for INP or OUT commands. The PIC32MX170 Family Data Sheet lists the details of this address space (RAM starts at 0xA0000000, Program Flash starts at 0x9D000000 and Boot Flash starts at 0x9FC00000).
PI	Returns the value of pi.
PIN(pin)	Returns the value on the external I/O 'pin'. Zero means digital low, 1 means digital high and for analogue inputs it will return the measured voltage as a floating point number. Frequency inputs will return the frequency in Hz. A period input will return the period in milliseconds while a count input will return the count since reset (counting is done on the positive rising edge). The count input can be reset to zero by resetting the pin to counting input (even if it is already so configured).

	<p>This function will also return the state of a pin configured as an output. Also see the SETPIN and PIN() = commands. Refer to the chapter <i>"Using the I/O pins"</i> for a general description of the Micromite's input/output capabilities.</p>
PORT(start, nbr [,start, nbr]...)	<p>Returns the value of a number of I/O pins in one operation.</p> <p>'start' is an I/O pin number and its value will be returned as bit 0. 'start'+1 will be returned as bit 1, 'start'+2 will be returned as bit 2, and so on for 'nbr' number of bits. I/O pins used must be numbered consecutively and any I/O pin that is invalid or not configured as an input will cause an error. The start/nbr pair can be repeated up to 25 times if additional groups of input pins need to be added.</p> <p>This function will also return the state of a pin configured as an output. It can be used to conveniently communicate with parallel devices like memory chips. Any number of I/O pins (and therefore bits) can be used from 1 to the number of I/O pins on the chip.</p> <p>See the PORT command to simultaneously output to a number of pins.</p>
POS	<p>Returns the current cursor position in the line in characters.</p>
PULSIN(pin, polarity) or PULSIN(pin, polarity, t1) or PULSIN(pin, polarity, t1, t2)	<p>Measures the width of an input pulse from 1µs to 1 second with 0.1µs resolution.</p> <p>'pin' is the I/O pin to use for the measurement, it must be previously configured as a digital input. 'polarity' is the type of pulse to measure, if zero the function will return the width of the next negative pulse, if non zero it will measure the next positive pulse.</p> <p>'t1' is the timeout applied while waiting for the pulse to arrive, 't2' is the timeout used while measuring the pulse. Both are in microseconds (µs) and are optional. If 't2' is omitted the value of 't1' will be used for both timeouts. If both 't1' and 't2' are omitted then the timeouts will be set at 100000 (ie, 100ms).</p> <p>This function returns the width of the pulse in microseconds (µs) or -1 if a timeout has occurred. With a CPU speed of 40MHz the measurement is accurate to ±0.5% and ±0.5µs. At other speeds the measurement is slightly less accurate.</p> <p>Note that this function will cause the running program to pause while the measurement is made and interrupts will be ignored during this period.</p>
RAD(degrees)	<p>Converts 'degrees' to radians.</p>
RGB(red, green, blue) or RGB(shortcut)	<p>Generates an RGB true colour value.</p> <p>'red', 'blue' and 'green' represent the intensity of each colour. A value of zero represents black and 255 represents full intensity.</p> <p>'shortcut' allows common colours to be specified by naming them. The colours that can be named are white, black, blue, green, cyan, red, magenta, yellow, brown and gray. For example, RGB(red) or RGB(cyan).</p> <p>Note that the value returned is an integer and, if it is to be stored in a variable, the variable should be declared as an integer to retain the accuracy of the number.</p>
RIGHT\$(string\$, number-of-chars)	<p>Returns a substring of 'string\$' with 'number-of-chars' from the right (end) of the string.</p>

RND(number)	Returns a pseudo-random number in the range of 0 to 0.999999. The 'number' value is ignored if supplied. The RANDOMIZE command reseeds the random number generator.																		
SGN(number)	Returns the sign of the argument 'number', +1 for positive numbers, 0 for 0, and -1 for negative numbers.																		
SIN(number)	Returns the sine of the argument 'number' in radians.																		
SPACE\$(number)	Returns a string of blank spaces 'number' characters long.																		
SQR(number)	Returns the square root of the argument 'number'.																		
STR\$(number) or STR\$(number, m) or STR\$(number, m, n) or STR\$(number, m, n, c\$)	<p>Returns a string in the decimal (base 10) representation of 'number'.</p> <p>If 'm' is specified sufficient spaces will be added to the start of the number to ensure that the number of characters before the decimal point (including the negative sign) will be at least 'm' characters. If 'm' is zero or the number has more than 'm' significant digits no padding spaces will be added.</p> <p>If 'm' is negative, positive numbers will be prefixed with the plus symbol and negative numbers with the minus symbol. If 'm' is positive then only the negative symbol will be used.</p> <p>'n' is the number of digits required to follow the decimal place. If it is zero the string will be returned without the decimal point. If it is negative the output will always use the exponential format with 'n' digits resolution. If 'n' is not specified the number of decimal places and output format will vary automatically according to the number.</p> <p>'c\$' is a string and if specified the first character of this string will be used as the padding character instead of a space (see the 'm' argument).</p> <p>Examples:</p> <table> <tr> <td>STR\$(123.456)</td><td>will return "123.456"</td></tr> <tr> <td>STR\$(123.456, 6)</td><td>will return " 123.456"</td></tr> <tr> <td>STR\$(123.456, -6)</td><td>will return " +123.456"</td></tr> <tr> <td>STR\$(-123.456, 6)</td><td>will return " -123.456"</td></tr> <tr> <td>STR\$(-123.456, 6, 5)</td><td>will return " -123.45600"</td></tr> <tr> <td>STR\$(-123.456, 6, -5)</td><td>will return " -1.23456e+02"</td></tr> <tr> <td>STR\$(53, 6)</td><td>will return " 53"</td></tr> <tr> <td>STR\$(53, 6, 2)</td><td>will return " 53.00"</td></tr> <tr> <td>STR\$(53, 6, 2, "*")</td><td>will return " *****53.00"</td></tr> </table>	STR\$(123.456)	will return "123.456"	STR\$(123.456, 6)	will return " 123.456"	STR\$(123.456, -6)	will return " +123.456"	STR\$(-123.456, 6)	will return " -123.456"	STR\$(-123.456, 6, 5)	will return " -123.45600"	STR\$(-123.456, 6, -5)	will return " -1.23456e+02"	STR\$(53, 6)	will return " 53"	STR\$(53, 6, 2)	will return " 53.00"	STR\$(53, 6, 2, "*")	will return " *****53.00"
STR\$(123.456)	will return "123.456"																		
STR\$(123.456, 6)	will return " 123.456"																		
STR\$(123.456, -6)	will return " +123.456"																		
STR\$(-123.456, 6)	will return " -123.456"																		
STR\$(-123.456, 6, 5)	will return " -123.45600"																		
STR\$(-123.456, 6, -5)	will return " -1.23456e+02"																		
STR\$(53, 6)	will return " 53"																		
STR\$(53, 6, 2)	will return " 53.00"																		
STR\$(53, 6, 2, "*")	will return " *****53.00"																		
STRING\$(nbr, ascii) or STRING\$(nbr, string\$)	Returns a string 'nbr' bytes long consisting of either the first character of string\$ or the character representing the ASCII value 'ascii' which is a decimal number in the range of 32 to 126.																		
TAB(number)	Outputs spaces until the column indicated by 'number' has been reached on the console output.																		
TAN(number)	Returns the tangent of the argument 'number' in radians.																		
TEMPR(pin)	<p>Return the temperature measured by a DS18B20 temperature sensor connected to 'pin' (which does not have to be configured). The CPU speed must be 20MHz or above.</p> <p>The returned value is degrees C with a default resolution of 0.25°C. If there</p>																		

	<p>is an error during the measurement the returned value will be 1000.</p> <p>The time required for the overall measurement is 200ms and interrupts will be ignored during this period. Alternatively the TEMPR START command can be used to start the measurement and your program can do other things while the conversion is progressing. When this function is called the value will then be returned instantly assuming the conversion period has expired. If it has not, this function will wait out the remainder of the conversion time before returning the value.</p> <p>The DS18B20 can be powered separately by a 3V to 5V supply or it can operate on parasitic power from the Micromite.</p> <p>See the chapter "Special Hardware Devices" for more details.</p>
TIME\$	<p>Returns the current time based on MMBasic's internal clock as a string in the form "HH:MM:SS" in 24 hour notation. For example, "14:30:00".</p> <p>To set the current time use the command TIME\$ = .</p>
TIMER	<p>Returns the elapsed time in milliseconds (eg, 1/1000 of a second) since reset. The timer is reset to zero on power up or a CPU restart and you can also reset it by using TIMER as a command. If not specifically reset it will continue to count up forever (it is a 64 bit number and will only roll over to zero after 200 million years).</p>
TOUCH(X) or TOUCH(Y)	<p>Will return the X or Y coordinate of the location currently touched on an LCD panel.</p> <p>If the screen is not being touched the function will return -1.</p>
UCASE\$(string\$)	<p>Returns 'string\$' converted to uppercase characters.</p>
VAL(string\$)	<p>Returns the numerical value of the 'string\$'. If 'string\$' is an invalid number the function will return zero.</p> <p>This function will recognise the &H prefix for a hexadecimal number, &O for octal and &B for binary.</p>

Obsolete Commands and Functions

These commands and functions are mostly included to assist in converting programs written for Microsoft BASIC. For new programs the corresponding commands in MMBasic should be used.

Note that these commands may be removed in the future to recover memory for other features.

IF condition THEN linenbr	For Microsoft compatibility a GOTO is assumed if the THEN statement is followed by a number. A label is invalid in this construct. New programs should use: IF condition THEN GOTO linenbr label
IRETURN	Returns from an interrupt when the interrupt destination was a line number or a label. New programs should use a user defined subroutine as an interrupt destination. In that case END SUB or EXIT sub will cause a return from the interrupt.
SPC(number)	This function returns a string of blank spaces 'number' bytes long. It is similar to the SPACE\$() function and is only included for Microsoft compatibility.
TROFF	Turns the trace facility off; see TRON.
TRON	Turns on the trace facility. This facility will print the number of each line (counting from the beginning of the program) in square brackets as the program is executed. This is useful in debugging programs. New programs should use the TRACE command.
WHILE expression WEND	WHILE initiates a WHILE-WEND loop. The loop ends with WEND, and execution reiterates through the loop as long as the 'expression' is true. This construct is included for Microsoft compatibility. New programs should use the DO WHILE ... LOOP construct.

Appendix A

Serial Communications

On the standard Micromite (28 or 44-pin) two serial ports are available for asynchronous serial communications labelled COM1: and COM2:. On the Micromite Plus (64 or 100-pin) up to four serial ports can be used (see the *Micromite Plus Manual* for the details).

After being opened the serial port will have an associated file number and you can use any commands that operate with a file number to read and write to/from it. A serial port is also closed using the CLOSE command.

The following is an example:

```
OPEN "COM1:4800" AS #5      \ open the first serial port with a speed of 4800 baud
PRINT #5, "Hello"           \ send the string "Hello" out of the serial port
dat$ = INPUT$(20, #5)        \ get up to 20 characters from the serial port
CLOSE #5                    \ close the serial port
```

The OPEN Command

A serial port is opened using the command:

```
OPEN comspec$ AS #fnbr
```

'fnbr' is the file number to be used. It must be in the range of 1 to 10. The # is optional.

'comspec\$' is the communication specification and is a string (it can be a string variable) specifying the serial port to be opened and optional parameters. The default is 9600 baud, 8 data bits, no parity and one stop bit.

It has the form "COMn: baud, buf, int, intlevel, DE, 9BIT, INV, OC, S2" where:

- 'n' is the serial port number for either COM1: or COM2:.
- 'baud' is the baud rate – see Baud Rate below for the limits in the speed Default is 9600.
- 'buf' is the receive buffer size in bytes (default size is 256). The transmit buffer is fixed at 256 bytes.
- 'int' is a user defined subroutine which will be called when the serial port has received some data. The default is no interrupt.
- 'intlevel' is the number of characters that must be waiting in the receive queue before the receive interrupt subroutine is called. The default is 1 character.

All parameters except the serial port name (COMn:) are optional. If any one parameter is left out then all the following parameters must also be left out and the defaults will be used.

Five options can be added to the end of 'comspec\$' These are DE, 9BIT, INV, OC and S2:

- 'DE' will enable the Data output Enable (EN) signal for RS485. See the section "IEEE 485" for details.
- '9BIT' will specify that 9 bit transmit and receive is to be used. See the section "IEEE 485" for details.
- 'INV' specifies that the transmit and receive polarity is inverted (COM1: only).
- 'OC' will force the transmit pin (and DE on COM1:) to be open collector. This option can be used on both COM1: and COM2:. The default is normal (0 to 3.3V) output.
- 'S2' specifies that two stop bits will be sent following each character transmitted. (COM1: only)

Input/Output Pin Allocation

When a serial port is opened the pins used by the port will be automatically set to input or output as required and the SETPIN and PIN commands will be disabled for the pins. When the port is closed (using the CLOSE command) all pins used by the serial port will be set to a not-configured state and the SETPIN command can then be used to reconfigure them.

The connections for each COM port are shown in the pinout diagrams in the beginning of this manual. Note that Tx means an output from the Micromite and Rx means an input to the Micromite. The enable pin (the EN signal for RS485) is an output.

The signal polarity is standard for devices running at TTL voltages (for RS232 voltages see below). Idle is voltage high, the start bit is voltage low, data uses a high voltage for logic 1 and the stop bit is voltage high. These signal levels allow you to directly connect to devices like GPS modules (which generally use TTL voltage levels).

When a serial port is opened MMBasic will enable an internal pullup resistor (to Vdd) on the Rx (receive data) pin. This has a value of about 100K and its purpose is to prevent the input from floating if it is left

unconnected. Normally this is fine but it can cause a problem if you have an external resistor in series with the Rx pin, in that case this resistor and the pullup resistor will form a voltage divider limiting how high or low the voltage on the Rx pin can swing and that in turn might mean that the input signal is not recognised. The solution is to use the embedded C routine *ChangePin* to turn off the pullup after the serial port has been opened. *ChangePin* is included in the Micromite distribution file (the zip file) in the *Embedded C Modules* folder.

Note that a pullup resistor is also applied to the console's Rx pin and it too can be disabled using *ChangePin*.

Baud Rate

On the 28 and 44-pin Micromites COM1: is implemented using the onboard UART in the PIC32 while COM2: is implemented in software and therefore cannot run as fast. The maximum speed for both COM ports is limited by the CPU's speed as listed below (the CPU speed can be changed with the CPU SPEED command):

CPU Speed	COM1: Maximum	COM2: Maximum
48 MHz	282000	19200
40 MHz (default)	230400	19200
30 MHz	115200	9600
20 MHz	115200	9600
10 MHz	57600	4800
5 MHz	38400	2400

Note that below these limits any baud rate can be chosen, for example 1111 bps is a valid speed for both ports. On the Micromite Plus much greater speeds can be specified for all four possible serial ports (see the *Micromite Plus Manual* for the details).

Examples

Opening a serial port using all the defaults:

```
OPEN "COM2:" AS #2
```

Opening a serial port specifying only the baud rate (4800 bits per second):

```
OPEN "COM2:4800" AS #1
```

Opening a serial port specifying the baud rate (9600 bits per second) and receive buffer size (1KB):

```
OPEN "COM1:9600, 1024" AS #8
```

The same as above but with two stop bits enabled:

```
OPEN "COM1:9600, 1024, S2" AS #8
```

An example specifying everything including an interrupt, an interrupt level, inverted and two stop bits:

```
OPEN "COM1:19200, 1024, ComIntLabel, 256, INV, S2" AS #5
```

Reading and Writing

Once a serial port has been opened you can use any command or function that uses a file number to write and read from the port. Generally the PRINT command is the best method for transmitting data and the INPUT\$() function is the most convenient way of getting data that has been received. When using the INPUT\$() function the number of characters specified will be the maximum number of characters returned but it could be less if there are less characters in the receive buffer. In fact the INPUT\$() function will immediately return an empty string if there are no characters available in the receive buffer.

The LOC() function is also handy; it will return the number of characters waiting in the receive buffer (ie, the number of characters that can be retrieved by the INPUT\$() function). The EOF() function will return true if there are no characters waiting. The LOF() function will return the space (in characters) remaining in the transmit buffer.

When outputting to a serial port (ie, using PRINT #n, dat) the data will be held in a memory buffer while the serial port is sending it. This means that MMBasic will continue running the program while the data is being transmitted. If you want to be sure that all the data has been sent (perhaps because you want to close the port) you should wait until the LOC() function returns zero indicating that there is nothing waiting to be sent. The one exception is if the output buffer is full and in that case MMBasic will pause and wait until there is sufficient space before continuing. If the receive buffer overflows with incoming data the serial port will automatically discard the oldest data to make room for the new data.

Serial ports can be closed with the CLOSE command. This will discard any characters waiting in the buffers, free the memory used by the buffers, cancel the interrupt (if set) and set all pins used by the port to the not configured state. A serial port is also automatically closed when commands such as RUN and NEW are issued.

Interrupts

The interrupt subroutine (if specified) will operate the same as a general interrupt on an external I/O pin (see the chapter "Using the I/O pins" for a description).

When using interrupts you need to be aware that it will take some time for MMBasic to respond to the interrupt and more characters could have arrived in the meantime, especially at high baud rates. For example, if you have specified the interrupt level as 200 characters and a buffer of 256 characters then quite easily the buffer will have overflowed by the time the interrupt subroutine can read the data. In this case the buffer should be increased to 512 characters or more.

Additional Serial Ports

Additional serial ports can be added to the Micromite by using the SerialTx and SerialRx embedded C modules. These are included in the "Embedded C Modules" folder in the Micromite firmware zip file.

IEEE 485

The 'DE' option in the OPEN comspec\$ for COM1: specifies that the Data output Enable (ENABLE) signal for the IEEE 485 protocol will be generated. This signal will appear on pin 7 on the 28-pin chip and is normally high. Just before a byte is transmitted this output will go low and when the byte has finished transmission the output will go high again. Note that this polarity is the opposite of that used in the Maximite family and an inverter is normally required to drive the DE input of an IEEE 485 transceiver.

Many IEEE 485 systems also use 9 bits of data for transmit and receive. The 9th bit is used to indicate that an address is being sent or received. To accommodate this the '9BIT' option in the OPEN comspec\$ for COM1: can be used. With this option all data sent must be sent in pairs of bytes – the first byte is the 9th bit and the second is the data (the other 8 bits). The first byte should be either the ASCII character '1' to indicate that the 9th bit should be set or '0' for not set. This 9th bit is then applied to the second byte in the pair and together they represent the 9 bits of data to send.

For example, the following fragment of code will send three 9 bit data items. The first is an address (bit 9 is high) and the second two are the data (bit 9 is low):

```
OPEN "COM1: 4800, 9BIT" as #1
PRINT "1" + CHR$(211);
PRINT "0" + CHR$(23);
PRINT "0" + CHR$(0);
```

Note that in the PRINT commands the automatic CR/LF is suppressed by the use of the semicolon.

Received data is similar. The 9bit data is translated into two characters – the first is the ASCII character '1' or '0' indicating the state of the 9th bit in the data received and the second character is the other 8 bits. This means that a BASIC program must read the data as pairs and apply logic to determine the value of the 9th bit (the first character) and then take the appropriate action with the second character.

For example:

```
IF LOC(#1) >= 2 THEN      ' check that we have at least two bytes
  A$ = INPUT$(1, #1) : B$ = INPUT$(1, #1)
  IF A$ = "1" THEN
    ' B$ contains an address
  ELSE
    ' B$ contains some data
  ENDIF
ENDIF
```

MMBasic does not check that data is printed or read to/from the COM port in pairs. If your program inadvertently sends or reads a single character it will disrupt all subsequent communications.

Note also that in 9 bit mode the size of the transmit and receive buffers are effectively halved because each 9 bit data item is stored as two bytes.

Low Cost RS-232 Interface

The RS-232 signalling system is used by modems, hardwired serial ports on a PC, test equipment, etc. It is the same as the serial TTL system used on the Micromite with two exceptions:

- The voltage levels of RS-232 are +12V and -12V where TTL serial uses +3.3V and zero volts.
- The signalling is inverted (the idle voltage is -12V, the start bit is +12V, etc).

It is possible to purchase cheap RS-232 to TTL converters on the Internet but it would be handy if the Micromite could directly interface to RS-232.

The first issue is that the signalling polarity is inverted with respect to TTL. On the Micromite COM1: can be specified to invert the transmit and receive signal (the 'INV' option) so that is an easy fix.

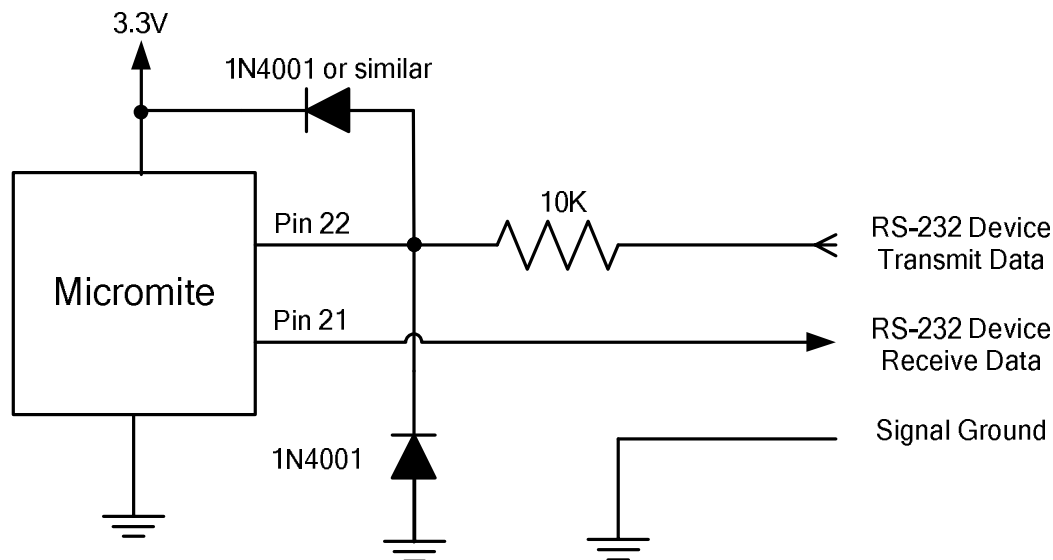
For the receive data (that is the $\pm 12\text{V}$ signal from the remote RS-232 device) it is easy to limit the voltage using a series resistor of (say) $10\text{k}\Omega$ and two diodes that will clamp the input voltage to the 3.3V rail and ground.

The input impedance of the Micromite is very high so the resistor will not cause a voltage drop but it does mean that when the signal swings to the maximum $\pm 12\text{V}$ it will be safely clipped by the diodes.

For the transmit signal (from the Micromite to the RS-232 device) you can connect this directly to the input of the remote device. The Micromite will only swing the signal from zero to 3.3V but most RS-232 inputs have a threshold of about +1V so the Micromite's signal will still be interpreted as a valid signal.

These measures break the rules for RS-232 signalling, but if you only want to use it over a short distance (a metre or two) it should work fine.

To summarise, use this circuit (the pin numbers are for a 28-pin chip):



And open COM1: with the invert option. For example:

```
OPEN "COM1: 4800, INV" AS #1
```

Appendix B

I²C Communications

The Inter Integrated Circuit (I²C) bus was developed by Philips (now NXP) for the transfer of data between integrated circuits. This implementation was written by Gerard Sexton and the standard definition of I²C is provided by this document: http://www.nxp.com/documents/user_manual/UM10204.pdf

There are four commands that can be used in I²C master mode:

- | | |
|---|--|
| I2C OPEN speed,
timeout [, PU] | Enables the I ² C module in master mode.

‘speed’ is a value between 10 and 400 (for bus speeds 10 kHz to 400 kHz).

‘timeout’ is a value in milliseconds after which the master send and receive commands will be interrupted if they have not completed. The minimum value is 100. A value of zero will disable the timeout (though this is not recommended).

‘PU’ (if specified) will enable weak pullups (about 100K) on both the clock and data lines. I2C normally requires lower value resistors (typically 10K) but for short signal lines at slow speed this may be all that is required. |
| I2C WRITE addr,
option, sendlen,
senddata [,senddata
....] | Send data to the I ² C slave device.

‘addr’ is the slave’s I ² C address.

‘option’ is a number between 0 and 3 (normally this is set to 0)
1 = Keep control of the bus after the command (a stop condition will not be sent at the completion of the command)
2 = Treat the address as a 10 bit address
3 = Combine 1 and 2 (hold the bus and use 10 bit addresses).

‘sendlen’ is the number of bytes to send.

‘senddata’ is the data to be sent - this can be specified in various ways (all values sent will be between 0 and 255): <ul style="list-style-type: none">• The data can be supplied as individual bytes on the command line.
 Example: I2C WRITE &H6F, 0, 3, &H23, &H43, &H25• The data can be in a one dimensional array specified with empty brackets (ie, no dimensions). ‘sendlen’ bytes of the array will be sent starting with the first element. Example: I2C WRITE &H6F, 0, 3, ARRAY()• The data can be a string variable (not a constant).
 Example: I2C WRITE &H6F, 0, 3, STRING\$ |
| I2C READ addr,
option, rcvlen, rcvbuf | Get data from the I ² C slave device.

‘addr’ is the slave’s I ² C address.

‘option’ is a number between 0 and 3 (normally this is set to 0)
1 = Keep control of the bus after the command (a stop condition will not be sent at the completion of the command)
2 = Treat the address as a 10 bit address
3 = Combine 1 and 2 (hold the bus and use 10 bit addresses).

‘rcvlen’ is the number of bytes to receive.

‘rcvbuf’ is the variable or array used to save the received data - this can be: <ul style="list-style-type: none">• A string variable. Bytes will be stored as sequential characters in the string.• A one dimensional array of numbers specified with empty brackets. Received bytes will be stored in sequential elements of the array starting with the first.
 Example: I2C READ &H6F, 0, 3, ARRAY()• A normal numeric variable (in this case rcvlen must be 1). |

I2C CLOSE	Disables the master I ² C module and returns the I/O pins to a "not configured" state. They can then be configured using SETPIN. This command will also send a stop if the bus is still held.
-----------	--

And similarly there are four commands for the slave mode:

I2C SLAVE OPEN addr, mask, option, send_int, rcv_int	<p>Enables the I²C module in slave mode.</p> <p>‘addr’ is the slave I²C address.</p> <p>‘mask’ is the address mask (normally 0, bits set as 1 will always match). This allows the slave to respond to multiple addresses.</p> <p>‘option’ is a number between 0 and 3 (normally this is set to 0).</p> <p style="padding-left: 20px;">1 = allows MMBasic to respond to the general call address. When this occurs the value of MM.I2C will be set to 4.</p> <p style="padding-left: 20px;">2 = treat the address as a 10 bit address</p> <p style="padding-left: 20px;">3 = combine 1 and 2</p> <p>‘send_int’ is the subroutine to be invoked when the module has detected that the master is expecting data.</p> <p>‘rcv_int’ is the subroutine to be called when the module has received data from the master. Note that this is triggered on the first byte received so your program might need to wait until all the data is received.</p>
I2C SLAVE WRITE sendlen, senddata [,senddata]	<p>Send the data to the I²C master. This command should be used in the send interrupt (ie in the 'send_int' subroutine when the master has requested data). Alternatively a flag can be set in the interrupt subroutine and the command invoked from the main program loop when the flag is set.</p> <p>‘sendlen’ is the number of bytes to send.</p> <p>‘senddata’ is the data to be sent. This can be specified in various ways, see the I2C WRITE commands for details.</p>
I2C SLAVE READ rcvlen, rcvbuf, rcvd	<p>Receive data from the I²C master device. This command should be used in the receive interrupt (ie in the 'rcv_int' subroutine when the master has sent some data). Alternatively a flag can be set in the receive interrupt subroutine and the command invoked from the main program loop when the flag is set.</p> <p>‘rcvlen’ is the maximum number of bytes to receive.</p> <p>‘rcvbuf’ is the variable to receive the data. This can be specified in various ways, see the I2C READ commands for details.</p> <p>‘rcvd’ is a variable that, at the completion of the command, will contain the actual number of bytes received (which might differ from ‘rcvlen’).</p>
I2C SLAVE CLOSE	Disables the slave I ² C module and returns the external I/O pins 12 and 13 to a "not configured" state. They can then be configured using SETPIN.

Following an I²C write or read command the automatic variable MM.I2C will be set to indicate the result of the operation as follows:

- 0 = The command completed without error.
- 1 = Received a NACK response
- 2 = Command timed out

Additional I²C Ports

Additional I²C master ports can be added to the Micromite by using the I2CPort embedded C module. This is included in the "Embedded C Modules" folder in the Micromite firmware zip file.

7 and 8 Bit Addressing

The standard addresses used in these commands are 7-bit addresses (without the read/write bit). MMBasic will add the read/write bit and manipulate it accordingly during transfers.

Some vendors provide 8-bit addresses which include the read/write bit. You can determine if this is the case because they will provide one address for writing to the slave device and another for reading from the slave. In these situations you should only use the top seven bits of the address.

For example: If the read address is 9B (hex) and the write address is 9A (hex) then using only the top seven bits will give you an address of 4D (hex). A simple way of finding the address is to take the 8 bit write address and divide it by 2.

Another indicator that a vendor is using 8-bit addresses instead of 7-bit addresses is to check the address range. All 7-bit addresses should be in the range of 08 to 77 (hex). If your slave address is greater than this range then probably your vendor has specified an 8-bit address.

10 Bit Addressing

10-bit addressing was designed to be compatible with 7-bit addresses, allowing developers to mix the two types of devices on a single bus. Devices that use 10-bit addresses will be clearly identified as such in their data sheets.

In 10-bit addressing the slave address is sent in two bytes with the first byte beginning with a special bit pattern to indicate that a 10 bit address is being used. This process is automatically managed by MMBasic when the 'option' argument is set for 10-bit addressing. 10-bit addresses can be in the range of 0 to 3FF (hex).

Master/Slave Modes

The master and slave modes can be enabled simultaneously; however, once a master command is in progress, the slave function will be "idle" until the master releases the bus. Similarly, if a slave command is in progress, the master commands will be unavailable until the slave transaction completes.

In master mode, the I²C send and receive commands will not return until the command completes or a timeout occurs (if the timeout option has been specified).

The slave mode uses an MMBasic interrupt to signal a change in status and in this routine the Micromite should write/read the data as specified by the I²C master. This operates the same as a general interrupt on an external I/O pin.

I/O Pins

Refer to pinout charts at the beginning of this manual for the pin numbers used for the I²C data line (SDA) and clock (SCL). Both of these pins should have external pullup resistors installed (typical values are 10 K Ω for 100kHz or 2 K Ω for 400kHz). Weak pullups (about 100K) on both the clock and data lines can also be specified in the I2C OPEN command. I2C normally requires lower value resistors but for short signal lines at slow speeds this may be all that is required.

When the I2C CLOSE command is used the I/O pins are reset to a "not configured" state. Then can then be configured as per normal using SETPIN.

When running the I²C bus at above 150 kHz the cabling between the devices becomes important. Ideally the cables should be as short as possible (to reduce capacitance) and also the data and clock lines should not run next to each other but have a ground wire between them (to reduce crosstalk).

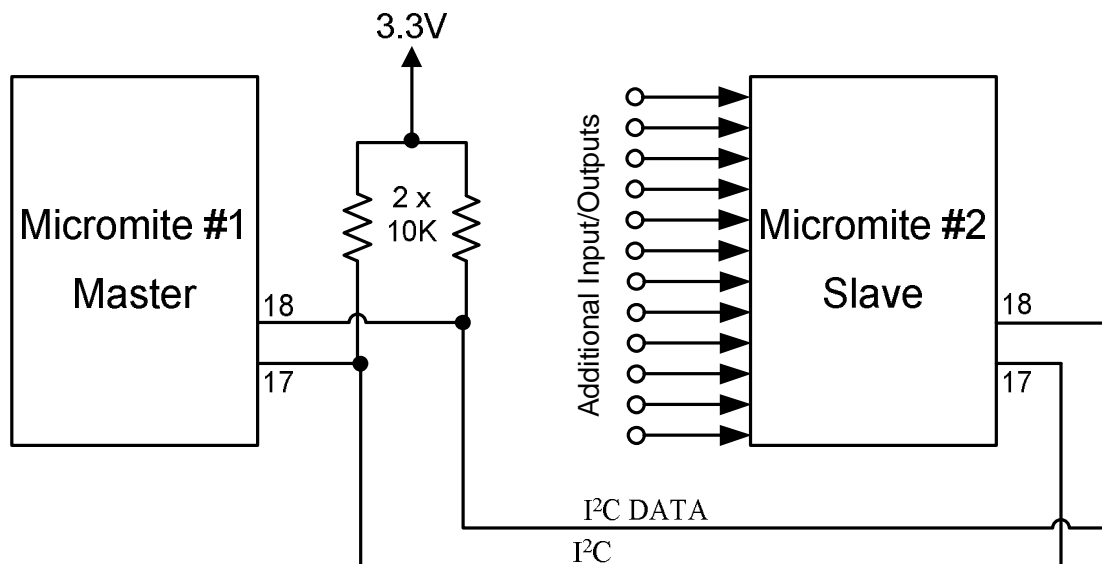
If the data line is not stable when the clock is high, or the clock line is jittery, the I²C peripherals can get "confused" and end up locking the bus (normally by holding the clock line low). If you do not need the higher speeds then operating at 100 kHz is the safest choice.

Example

I²C is ideally suited for communications between integrated circuits. As an example, there might be an occasion when a single Micromite or Maximite does not have enough serial ports, I/O pins, or whatever for a particular application. In that case a Micromite could be used as a slave to provide the extra facilities.

This example converts a Micromite into a general purpose I/O expansion chip with 17 I/O pins that can be dynamically configured (by the master) as analog inputs or digital input/outputs. The routines on the master are simple to use (SSETPIN to configure the slave I/O and SPIN() to control it) and the program running on the master need not know that the physical I/O pins reside on another chip. All communications are done via I²C.

The following illustration shows the connections required for 28-pin chips:



Program Running On the Slave:

The slave must first set up its I²C interface to respond to requests from the master. With that done it can then drop into an infinite loop while the job of responding to the master is handled by the I²C interrupts.

In the program below the slave will listen on I²C address 26 (hex) for a three byte command from the master. The format of this message is:

- Byte 1 is the command type. It can have one of three values; 1 means configure the pin, 2 means set the output of the pin and 3 means read the input of the pin.
- Byte 2 is the pin number to operate on.
- Byte 3 is the configuration number (if the command byte is 1), the output of the pin (if the command byte is 2) or a dummy number (if the command byte is 3).

The configuration number used when configuring a slave's I/O pin is the same as used in earlier versions of Maximite MMBasic (with the SETPIN command) and can be any one of:

- | | |
|---|---|
| 0 | Not configured or inactive |
| 1 | Analog input |
| 2 | Digital input |
| 3 | Frequency input |
| 4 | Period input |
| 5 | Counting input |
| 8 | Digital output |
| 9 | Open collector digital output. In this mode SPIN() will also return the value on the output pin . |

Following a command from the master that requests an input, the master must then issue a second I²C command to read 12 bytes. The slave will respond by sending the value as a 12 character string.

This program can fall over if the master issues an incorrect command. For example, by trying to read from a pin that is not an input. If that occurs, an error will be generated and MMBasic will exit to the command prompt.

Rather than trap all the possible errors that the master can make, this program uses the watchdog timer. If an error does occur the watchdog timer will simply reboot the Micromite and the program will restart (because AUTORUN is on) and wait for the next message from the master. The master can tell that something was wrong because it would get a timeout.

This is the complete program running on the slave:

```
OPTION AUTORUN ON
DIM msg(2) ' array used to hold the message
I2C SLAVE OPEN &H26, 0, 0, Writed, ReadD ' slave's address is 26 (hex)

DO ' the program loops forever
  WATCHDOG 1000 ' this will recover from errors
LOOP

SUB ReadD ' received a message
  I2C SLAVE READ 3, msg(), recvd ' get the message into the array
  IF msg(0) = 1 THEN ' command = 1
    SETPIN msg(1), msg(2) ' configure the I/O pin
  ELSEIF msg(0) = 2 THEN ' command = 2
    PIN(msg(1)) = msg(2) ' set the I/O pin's output
  ELSE ' the command must be 3
    s$ = str$(pin(msg(1))) + Space$(12) ' get the input on the I/O pin
  ENDIF
END SUB ' return from the interrupt

SUB Writed ' request from the master
  I2C SLAVE WRITE 12, s$ ' send the last measurement
END SUB ' return from the interrupt
```

Interface Routines On the Master:

These routines can be run on another Micromite or a Maximate or some other computer with an I²C interface. They assume that the slave Micromite is listening on I²C address 26 (hex).

If necessary these can be modified to access multiple Micromites (with different addresses), all acting as expansion chips and providing an almost unlimited expansion capability.

There are two subroutines and one function that together are used to control the slave:

SSETPIN pin, cfg	This subroutine will setup an I/O pin on the slave. It operates the same as the MMBasic SETPIN command and the possible values for 'cfg' are listed above.
SPIN pin, output	This subroutine will set the output of the slave's pin to 'output' (ie, high or low).
nn = SPIN(pin)	This function will return the value of the input on the slave's I/O pin.

For example, to display the voltage on pin 3 of the slave you would use:

```
SSETPIN 3, 1
PRINT SPIN(3)
```

As another example, to flash a LED connected to pin 15 of the slave you would use:

```
SSETPIN 15, 8
SPIN 15, 1
PAUSE 300
SPIN 15, 0
```

These are the three routines:

```
' configure an I/O pin on the slave
SUB SSETPIN pinnbr, cfg
  I2C OPEN 100, 1000
  I2C WRITE &H26, 0, 3, 1, pinnbr, cfg
  IF MM.I2C THEN ERROR "Slave did not respond"
  I2C CLOSE
END SUB
```

```

' set the output of an I/O pin on the slave
SUB SPIN pinnbr, dat
  I2C OPEN 100, 1000
  I2C WRITE &H26, 0, 3, 2, pinnbr, dat
  IF MM.I2C THEN ERROR "Slave did not respond"
  I2C CLOSE
END SUB

```

```

' get the input of an I/O pin on the slave
FUNCTION SPIN(pinnbr)
  LOCAL t$
  I2C OPEN 100, 1000
  I2C WRITE &H26, 0, 3, 3, pinnbr, 0
  I2C READ &H26, 0, 12, t$
  IF MM.I2C THEN ERROR "Slave did not respond"
  I2C CLOSE
  SPin = VAL(t$)
END FUNCTION

```

Appendix C

1-Wire Communications

The 1-Wire protocol was developed by Dallas Semiconductor to communicate with chips using a single signalling line. This implementation was written for MMBasic by Gerard Sexton.

There are three commands that you can use:

ONEWIRE RESET pin	Reset the 1-Wire bus
ONEWIRE WRITE pin, flag, length, data [, data...]	Send a number of bytes
ONEWIRE READ pin, flag, length, data [, data...]	Get a number of bytes

Where:

pin - The Micromite I/O pin to use. It can be any pin capable of digital I/O.

flag - A combination of the following options:

- 1 - Send reset before command
- 2 - Send reset after command
- 4 - Only send/recv a bit instead of a byte of data
- 8 - Invoke a strong pullup after the command (the pin will be set high and open drain disabled)

length - Length of data to send or receive

data - Data to send or variable to receive.

The number of data items must agree with the length parameter.

And the automatic variable

MM.ONEWIRE	Returns true if a device was found
------------	------------------------------------

Note: The CPU speed must be 10 MHz or above.

After the command is executed, the I/O pin will be set to the not configured state unless flag option 8 is used.

When a reset is requested the automatic variable MM.ONEWIRE will return true if a device was found. This will occur with the ONEWIRE RESET command and the ONEWIRE READ and ONEWIRE WRITE commands if a reset was requested (flag = 1 or 2).

For users of MMBasic on earlier devices

This implementation of the 1-Wire protocol is generally compatible with previous versions with the following differences:

- The commands are now two words where previously they were one word. For example, OWWRITE is now ONEWIRE WRITE.
- You cannot use an array or string variable for 'data'. One or more numeric variables are required.
- The reset command (ONEWIRE RESET) does not accept a 'presence' variable (use the MM.ONEWIRE variable instead).
- The OWSEARCH command and the OWCRC8() and OWCRC16() functions are not implemented.

The 1-Wire protocol is often used in communicating with the DS18B20 temperature measuring sensor and to help in that regard MMBasic includes the TEMPR() function which provides a convenient method of directly reading the temperature of a DS18B20 without using these functions.

Appendix D

SPI Communications

The Serial Peripheral Interface (SPI) communications protocol is used to send and receive data between integrated circuits. The Micromite acts as the master (ie, it generates the clock).

I/O Pins

The SPI OPEN command will automatically configure the relevant I/O pins. The SPI pinouts are listed at the start of the manual. MISO stands for Master In Slave Out and because the Micromite is always the master that pin will be configured as an input. Similarly MOSI stands for Master Out Slave In and that pin will be configured as an output.

When the SPI CLOSE command is used these pins will be returned to a "not configured" state. They can then be configured as per normal using SETPIN.

SPI Open

To use the SPI function the SPI channel must be first opened.

The syntax for opening the SPI channel is:

```
SPI OPEN speed, mode, bits
```

Where:

- 'speed' is the speed of the clock. It is a number representing the clock speed in Hz. The maximum is one quarter the CPU speed (ie, 10000000 at a CPU speed of 40 MHz).
- 'mode' is a single numeric digit representing the transmission mode – see Transmission Format below.
- 'bits' is the number of bits to send/receive. This can be 8, 16 or 32.
- It is the responsibility of the program to separately manipulate the CS (chip select) pin if required.

Transmission Format

The most significant bit is sent and received first. The format of the transmission can be specified by the 'mode' as shown below. Mode 0 is the most common format.

Mode	Description	CPOL	CPHA
0	Clock is active high, data is captured on the rising edge and output on the falling edge	0	0
1	Clock is active high, data is captured on the falling edge and output on the rising edge	0	1
2	Clock is active low, data is captured on the falling edge and output on the rising edge	1	0
3	Clock is active low, data is captured on the rising edge and output on the falling edge	1	1

For a more complete explanation see: http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

Standard Send/Receive

When the SPI channel is open data can be sent and received using the SPI function. The syntax is:

```
received_data = SPI(data_to_send)
```

Note that a single SPI transaction will send data while simultaneously receiving data from the slave. 'data_to_send' is the data to send and the function will return the data received during the transaction. 'data_to_send' can be an integer or a floating point variable or a constant.

If you do not want to send any data (ie, you wish to receive only) any number (eg, zero) can be used for the data to send. Similarly if you do not want to use the data received it can be assigned to a variable and ignored.

Bulk Send/Receive

Data can also be sent in bulk:

```
SPI WRITE nbr, data1, data2, data3, ... etc
```

or

```
SPI WRITE nbr, string$
```

or

```
SPI WRITE nbr, array()
```

In the first method 'nbr' is the number of data items to send and the data is the expressions in the argument list (ie, 'data1', data2' etc). The data can be an integer or a floating point variable or a constant.

In the second or third method listed above the data to be sent is contained in the 'string\$' or the contents of 'array()' (which must be a single dimension array of integer or floating point numbers). The string length, or the size of the array must be the same or greater than nbr. Any data returned from the slave is discarded.

Data can also be received in bulk:

```
SPI READ nbr, array()
```

Where 'nbr' is the number of data items to be received and array() is a single dimension integer array where the received data items will be saved. This command sends zeros while reading the data from the slave.

SPI Close

If required the SPI channel can be closed as follows (the I/O pins will be set to inactive):

```
SPI CLOSE
```

Additional SPI Ports

Additional SPI ports can be added to the Micromite by using the SPIPort embedded C module. This is included in the "Embedded C Modules" folder in the Micromite firmware zip file.

Using the SPI with the Colour LCD and Touch Features

The Micromite has only one standard SPI channel so this must be shared between the display and touch controllers (if these features are used) and the BASIC program. To do this the SPI port must be opened in BASIC and closed again without any intervening commands that might cause MMBasic to send/receive data to the display or touch controllers. This includes commands such as CLS, LINE, etc and the TOUCH() function.

The following provides an example. The SPI port is opened and closed within the one function with no intervening graphic or touch commands:

```
PIN(26) = 1          ' preset the pin high before it is setup
SETPIN 26, DOUT      ' pin 26 will be used as the enable signal
CIRCLE 100, 100, 50   ' draw a circle (uses the SPI port)
nbr% = ReadSPI%()    ' get the SPI data
x% = TOUCH(X)        ' get the X touch location (uses the SPI port)
nbr2% = ReadSPI%()   ' get the SPI data for a second time
y% = TOUCH(Y)        ' get the Y touch location (uses the SPI port)
END

' function to get the SPI data
FUNCTION ReadSPI%()
  SPI OPEN 4000000,0,8  ' 4meg speed, mode 0, 8bits
  PIN(26) = 0          ' chip select low
  SPI write 3,3,0,0     ' send a command
  SPI read 1, ReadSPI%  ' and get the response
  PIN(26) = 1          ' chip select high
  SPI CLOSE
END FUNCTION
```

Examples

The following example shows how to use the SPI port for general I/O. It will send a command 80 (hex) and receive two bytes from the slave SPI device using the standard send/receive function:

```
PIN(10) = 1 : SETPIN 10, DOUT  ' pin 10 will be used as the enable signal
SPI OPEN 5000000, 3, 8         ' speed is 5MHz and the data size is 8 bits
PIN(10) = 0                   ' assert the enable line (active low)
junk = SPI(&H80)               ' send the command and ignore the return
byte1 = SPI(0)                 ' get the first byte from the slave
byte2 = SPI(0)                 ' get the second byte from the slave
PIN(10) = 1                   ' deselect the slave
SPI CLOSE                     ' and close the channel
```


The following is similar to the example given above but this time the transfer is made using the bulk send/receive commands:

```
OPTION BASE 1                                ' our array will start with the index 1
DIM data%(2)                                ' define the array for receiving the data
PIN(10) = 1 : SETPIN 10, DOUT                ' pin 10 will be used as the enable signal
SPI OPEN 5000000, 3, 8                       ' speed is 5MHz, 8 bits data
PIN(10) = 0                                  ' assert the enable line (active low)
SPI WRITE 1, &H80                             ' send the command
SPI READ 2, data%()                          ' get two bytes from the slave
PIN(10) = 1                                  ' deselect the slave
    SPI CLOSE                                ' and close the channel
```