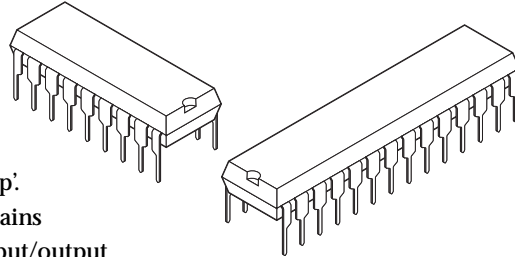


INTRODUCTION TO THE PICAXE SYSTEM



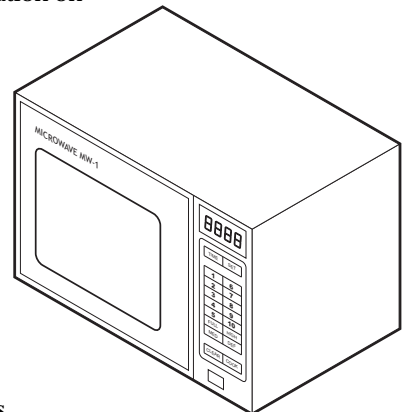
A PIC microcontroller is often described as a 'computer-on-a-chip'. It is an integrated circuit that contains memory, processing units, and input/output circuitry in a single unit.

Microcontrollers are purchased 'blank' and then programmed with a specific control program. Once programmed the microcontroller is built into a product to make the product more intelligent and easier to use.

As an example, a microwave oven may use a single microcontroller to process information from the keypad, display user information on the seven segment display, and control the output devices (turntable motor, light, bell and magnetron).

One microcontroller can often replace a number of separate parts, or even a complete electronic circuit. Some of the advantages of using microcontrollers in a product design are:

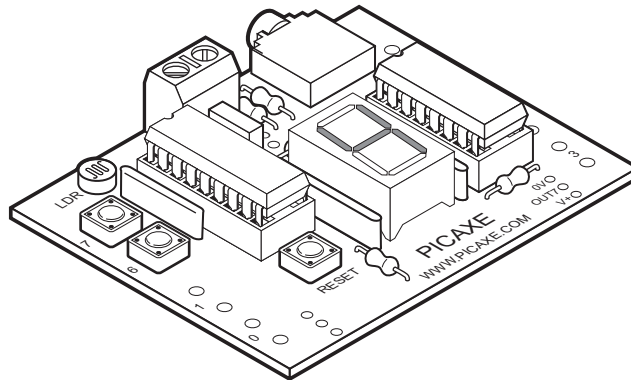
- increased reliability through a smaller part count
- reduced stock levels, as one microcontroller replaces several parts
- simplified product assembly and smaller end products
- greater product flexibility and adaptability since features are programmed into the microcontroller and not built into the electronic hardware
- rapid product changes or development by changing the program and not the electronic hardware



Applications that use microcontrollers include household appliances, alarm systems, medical equipment, vehicle subsystems, and electronic instrumentation. Some modern cars contain over thirty microcontrollers - used in a range of subsystems from engine management to remote locking!

In industry microcontrollers are usually programmed using the assembler or 'C' programming languages. However the complexity of these languages means that it is not realistic for younger students to be able to successfully use these languages within KS3 or 4 coursework.

THE PICAXE SYSTEM



The 'PICAXE' system is an easy-to-program microcontroller system that uses a simple BASIC language, which most students can learn very quickly. The PICAXE system exploits the unique characteristics of the new generation of low-cost 'FLASH' memory based microcontrollers. These microcontrollers can be programmed over and over again without the need for an expensive PIC programmer.

The power of the PICAXE system is its simplicity. No programmer, eraser or complicated electronic system is required - the microcontroller is programmed (with a simple 'BASIC' program or flowchart) via a 3-wire connection to the computers serial port. The operational PICAXE circuit uses just 3 components and can be easily constructed on a prototyping breadboard, strip-board or PCB design.

The PICAXE system is available in two types – 18 pin and 28 pin. The PICAXE-28 microcontroller provides 22 input/output pins - 8 digital outputs, 8 digital inputs and 4 analogue inputs. The PICAXE-18 system provides 8 outputs and 5 inputs.

The main features of the PICAXE system are as follows:

- low-cost, simple to construct circuit
- up to 8 inputs, 8 outputs and 4 analogue channels
- rapid download via serial cable
- free, easy to use Programming Editor software
- simple to learn BASIC language
- included flowchart editor
- can also be programmed via Crocodile Technology software.
- extensive free manuals and online support forum
- tutorial board and tutorials available
- infrared remote control upgrade pack available
- servo controller upgrade pack available

TUTORIAL 1 – THE PICAXE SYSTEM

The PICAXE system consists of three main components:

The 'Programming Editor' software

This software runs on a computer and allows you to use the computer keyboard to type in programs in a simple BASIC language. Programs can also be generated by drawing flowcharts. Alternately the 'Crocodile Technology' software may be used to simulate complete electronic circuits, programmed via flowcharts. Please see the Crocodile Technology appendix for more information.

The Serial Cable

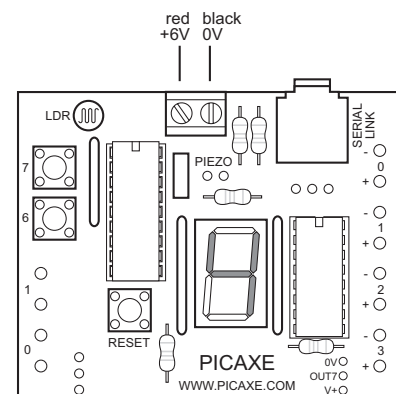
This is the cable that connects the computer to the PICAXE system. The cable only needs to be connected when downloading programs. It does not have to be connected when the PICAXE is running because the program is permanently stored on the PICAXE chip – even when the power supply is removed!

Two types of download cable are available - when using the tutorial board either cable may be used - connected to the three pin header or the stereo jack socket.

The PICAXE chip and board

The PICAXE microcontroller chip 'runs' program that have been downloaded to it. However the chip needs to be mounted on an electronic board that provide connection to the microcontroller chip.

The electronic board can be designed by the user on a piece of stripboard or printed circuit board, or a pre-made interface or tutorial board may be used for speed and convenience. This course presumes use of a PICAXE-18 (18 pin) microcontroller mounted on the tutorial board.



Summary - Programming Procedure

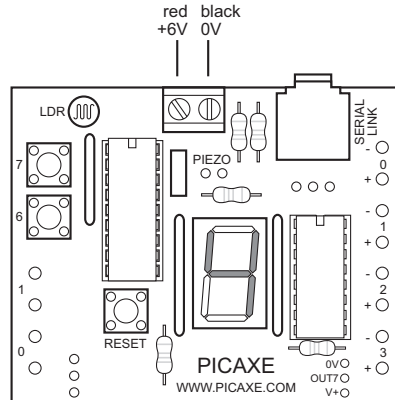
1. Write the program on the computer using the Programming Editor software.
2. Connect the download cable from the computer to the PICAXE.
3. Connect the battery pack to the PICAXE.
4. Use the Programming Editor software to download the program. The download cable can then be removed after the download.

The program will start running on the PICAXE automatically. However the program can also be restarted at any time by pressing the reset switch.

PICAXE-18 Boards

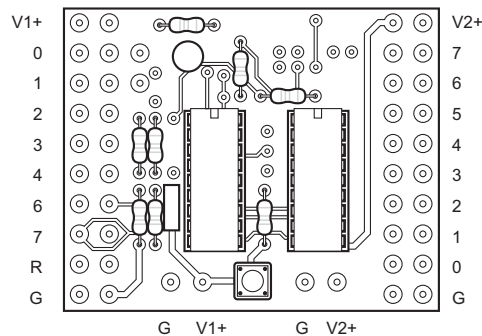
Three types of PICAXE18 project / tutorial boards are available

Tutorial Board



This is a tutorial board containing switches, sensors, a seven segment display and output drivers. This is the board described in these notes.

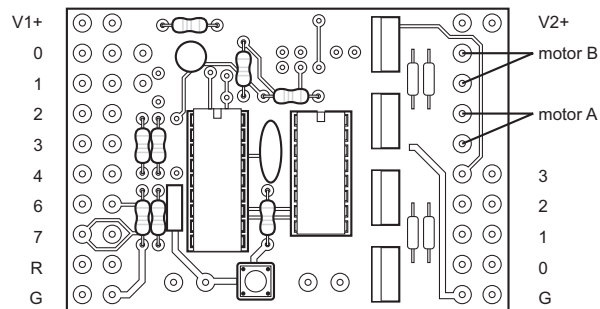
Standard Project Board



This is a project board that provides 8 digital (on/off) outputs via a darlington driver IC.

High Power Project Board

This is a project that provides 4 digital outputs (via FET drivers) and 2 reversible motor

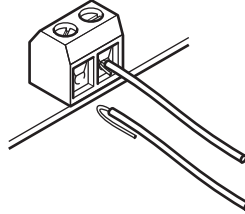


outputs.

Preparing the Tutorial Board

As supplied new, the tutorial board requires the battery clip to be connected before use.

Battery Box



Locate the battery clip, and fold the bare wire back over the insulation on each wire. Place the red wire in the socket marked 'V+' and the black wire in the socket marked '0V'. Tighten the screw so that the insulation and bare wire are both trapped in the socket – this provides a stronger joint than just trapping the bare wire.

Always use the 6V battery box (4 AA cells required) with the tutorial board. DO NOT use a 9V PP3 battery.

Solder Resist

The tutorial board is manufactured using a wave soldering technique. To prevent solder sticking to the spare holes (for optional components) a 'peelable solder resist' layer is printed on the base of the board. This peelable resist must be peeled off before the optional components may be soldered in place.

Installing the Software

Computer Requirements:

Windows 95/98/ME/NT/2000/XP

The software is supplied on CDROM, which should autostart when placed in the computer. If the CROM does not autostart use your browser (e.g. Explorer) to open the file index.htm.

You should then install the 'Programming Editor' software by following the on-screen instructions. If not already installed on your computer, you should also install the Adobe Acrobat Reader software, which is required for reading the help manuals.

Downloading a Sample Program

The following program switches output 7 on and off every second. When you download this program the decimal point on the seven segment display on the tutorial board should flash on and off every second.

```
main:
    high 7
    pause 1000
    low 7
    pause 1000
    goto main
```

This program uses the high and low commands to control output pin 7, and uses the pause command to make a delay (1000 ms = 1 second).

The last goto main command makes the program 'jump' back to the label main: at the start of the program. This means the program loops forever. Note that the first time the label is used it must be followed by the colon (:) symbol. This tells the computer the word is a new label.

Detailed instructions:

1. Connect the PICAXE cable to the computer serial port. Note which port it is connected to (normally labelled COM1 or COM2).
1. Start the Programming Editor software.
2. Select View>Options to select the Options screen (this may automatically appear).
3. Click on the 'Mode' tab and select PICAXE-18
4. Click on the 'Serial Port' tab and select the serial port that the PICAXE cable is connected to. Click 'OK'
5. Type in the following program:

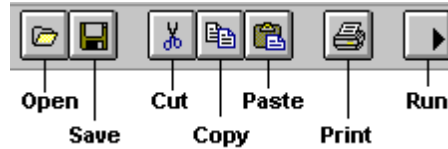
```
main:
    high 7
    pause 1000
    low 7
    pause 1000
    goto main
```

(NB note the colon (:) directly after the label 'main' and the spaces between the commands and numbers)

6. Make sure the PICAXE circuit is connected to the serial cable, and that the batteries are connected.
7. Select PICAXE>Run. A download bar should appear as the program downloads. When the download is complete the program should start running automatically – the decimal point LED on output 7 should flash on and off every second.

Windows Software Instructions

Toolbar short-cuts:



To download/run a program:

1. Check the download cable is connected to the PICAXE and the computer's serial port
2. Check that the power supply / battery is connected to the PICAXE
3. Make sure the Programming Editor software is in the correct mode (look for 'PICAXE-18' in the statusbar at the bottom left of the screen).
4. Click Run (or the toolbar icon)

To save a program:

1. Click File - Save As... (or the toolbar icon)
2. Type in a filename
3. Click <OK>

To open a saved program:

1. Click File - Open... (or the toolbar icon)
2. Select a filename from the list by clicking on it
3. Click <OK>

To start a new program:

1. Click File - New

To print a program:

1. Click File - Print... (or the toolbar icon)
2. If you want each program line printed to have a number, make sure the 'Print Line Numbers' box is checked
3. Click <OK>

TUTORIAL 2 - USING SYMBOLS

Sometimes it can be hard to remember which pins are connected to which devices. The 'symbol' command can then be used at the start of a program to rename the inputs and outputs. Note this program assumes connection of an external buzzer to output pin 1.

```
symbol dp = 7           ' rename output7 'dp' (decimal point)
symbol buzzer = 1       ' rename output1 'buzzer'

main:                   ' make a label called 'main'
    high dp             ' LED on
    low buzzer          ' buzzer off
    wait 1              ' wait 1 second
    low dp              ' LED off
    high buzzer         ' buzzer on
    wait 1              ' wait 1 second
    goto main           ' jump back to the start
```

Remember that comments (an explanation after the apostrophe (') symbol) can make each line of a program much easier to understand. These comments are ignored by the computer when it downloads a program to the PICAXE

A label (e.g. main: in the program above) can be any word (apart from keywords such as 'switch'), but must begin with a letter. When the label is first defined it must end with a colon (:). The colon 'tells' the computer that the word is a new label.

This program uses the wait command. The commands wait and pause both create time delays. However wait can only be used with whole seconds, pause can be used for shorter time delays (measured in milliseconds (1000th of a second)).

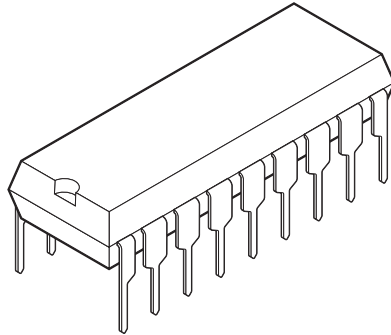
Wait can be followed by a number between 1 and 65.

Pause can be followed by a number between 1 and 65535.

It is also a good programming technique to use tabs (or spaces) at the start of lines without labels so that all the commands are neatly aligned. The term 'white-space' is used by programmers to define tabs, spaces and blank lines, and the correct use of white-space can make the program listing much easier to read and understand.

Note:

Some early BASIC languages used 'line numbers' rather than labels for 'goto' commands. Unfortunately this line number system can be inconvenient to use, because if you modify your program by later adding, or removing, lines of code you then have to modify all the line numbers within the 'goto' commands accordingly. The label system, as used in most modern BASIC languages, overcomes this problem automatically.



The 'brain' of the PICAXE system is the 18 pin PIC16F627 microcontroller. Although microcontrollers are relatively cheap (some microcontrollers cost less than £1) microcontrollers are very complex devices containing many thousands of transistors, resistors and other electronic components.

The PICAXE microcontroller stores its program in non-volatile FLASH memory. This means it does not lose the program when the power is removed from the circuit – when the battery is re-connected the program will start again. However when you wish to reprogram the PICAXE a new program can be downloaded – this erases the old program and writes the new program into the memory. Only one program can be in memory at one time.

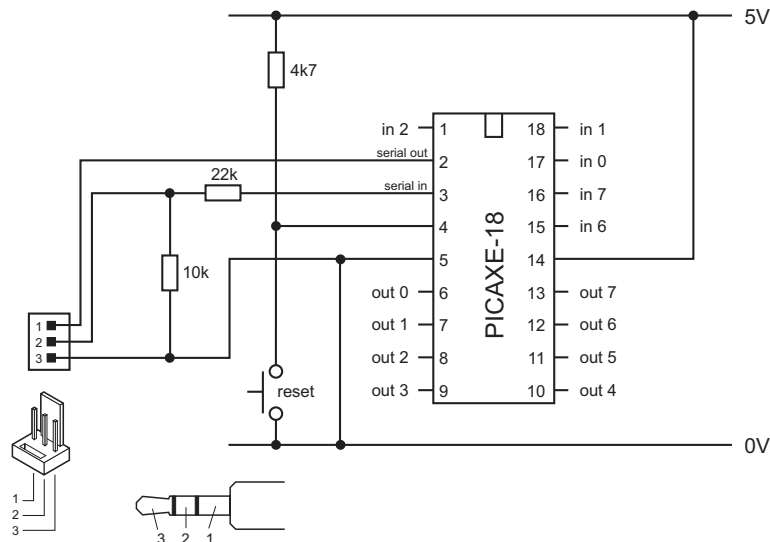
Note that it is not possible to 'read' the program back out of the PICAXE memory. Therefore you must save the program on the computer (before it is downloaded) if you wish to keep your program to use in the future.

As well as the program ROM memory (Read Only Memory) the microcontroller also contains temporary RAM (Random Access memory).

RAM (Random Access Memory) is 'temporary' memory used for storing information whilst the program is running. This is normally used to store answers to mathematical 'sums' the microcontroller carries out as it is working. This memory is 'volatile', which means that as soon as the power is disconnected the contents of the memory is lost. There are 14 bytes of temporary memory that can be used within programs, and these are labelled b0 to b13 within programs.

The PICAXE-18 Circuit

The basic PICAXE-18 circuit is shown below.



The 4k7 resistor is used to pull the PICAXE microcontrollers reset pin (pin 4) high. If desired, a reset switch can also be connected between the reset pin (pin 4) and 0V. When the switch is pushed the PICAXE microcontroller 'resets' to the first line in the program.

The PICAXE-18 microcontroller

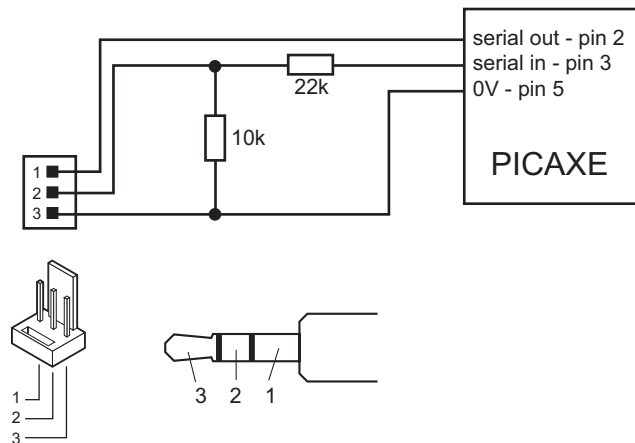
Please note that the PICAXE microcontroller is not a blank microcontroller! The PICAXE microcontroller is pre-programmed with a bootstrap program that enables the direct cable download. Blank microcontrollers will not contain this bootstrap program and so cannot be programmed from within the PICAXE system

The PICAXE-18A microcontroller

The PICAXE-18A microcontroller is almost identical to the standard PICAXE-18 microcontroller, but is slightly more expensive as it has twice as much program memory space (approx. 80 BASIC program lines instead of 40) and high resolution (rather than low-resolution) analogue inputs.

The PICAXE computer interface circuit

The PICAXE system uses a very simple interface to the computer serial port. Although this interface does not use true RS232 voltages, it is very low-cost and has proved to work reliably on almost all modern computers.



It is strongly recommended that this interfacing circuit is included on every PCB designed to be used with the PICAXE microcontroller. This enables the PICAXE microcontroller to be re-programmed without removing from the PCB.

Note:

Most modern computers have two serial ports, normally labelled COM1 and COM2. The Programming Editor software must be configured for the correct port – select View>Options>Serial Port to select the correct serial port for your machine.

When using a computer with the older 25-pin serial port connector, use a 9-25 way mouse adapter to convert the 9-pin PICAXE cable. These adapters can be purchased from all good high street computer stores.

TUTORIAL 3 - FOR...NEXT LOOPS

It is often useful to repeat the same part of a program a number of times, for instance when flashing a LED. In these cases a for...next loop can be used.

This program flashes the LED connected to output pin 7 on and off 15 times. The number of times the code has been repeated is stored in the RAM memory of the PICAXE chip using variable b0 (the PICAXE contains 14 general purpose byte variables labelled b0 to b13). These variables can also be renamed using the symbol command to make them easier to remember.

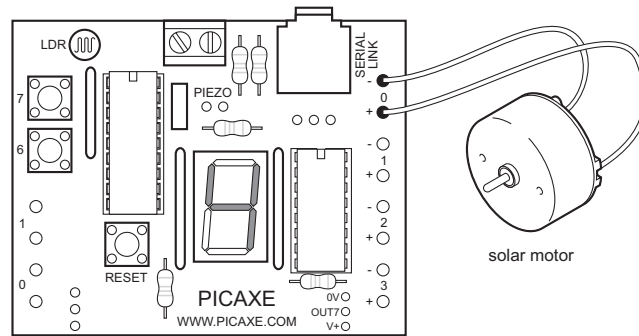
```
symbol counter = b0      ' define the variable "counter"
symbol dp = 7            ' define pin 7 with the name "dp"

main: for counter = 1 to 15 ' start a for...next loop
      high dp              ' switch pin 7 high
      pause 500            ' wait for 0.5 second
      low dp               ' switch pin 7 low
      pause 500            ' wait for 0.5 second
next counter              ' end of for...next loop

end                        ' end program
```

Note again how white-space (extra spaces) has been used to clearly show all the commands that are contained between the for and next commands.

Controlling the speed of a motor



As the PICAXE system operates very quickly, it is possible to control the speed of motors by switching them on and off very quickly. This type of control is known as Pulse Width Modulation (PWM). PWM is a good control technique because it allows the motors to work at a low speed whilst still maintaining a high torque (“turning force”). PWM is often used, for instance to control the speed of an electric drill or screwdriver. For PWM to work correctly you need a high quality motor. These programs are designed for a ‘solar’ motor and may not work correctly with a cheap toy motor.

```

symbol mark1 = b6      \ rename variables - easier to remember
symbol space1 = b7
symbol mark2 = b8
symbol space2 = b9

let mark1 = 2           \ preload mark1 / space1 with ratio 2:10 (1:5)
let space1 = 10

let mark2 = 20          \ preload mark2 / space2 with ratio 20:10 (2:1)
let space2 = 10

main:
  for b2 = 1 to 200      \ start a for...next loop
    high 0               \ motor on
    pause mark1          \ wait mark1 time
    low 0                \ motor off
    pause space1         \ wait space1 time
  next b2               \ next loop

  pause 2000            \ stop motor for 2 seconds

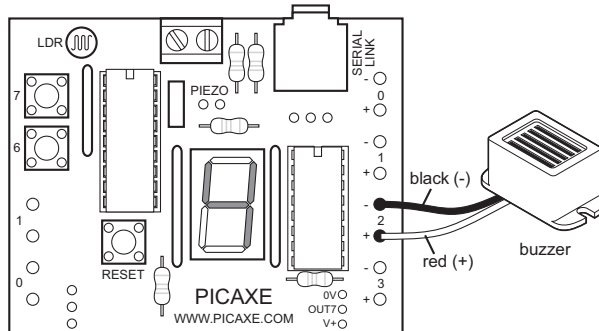
  for b2 = 1 to 200      \ start a for...next loop
    high 0               \ motor on
    pause mark2          \ wait mark2 time
    low 0                \ motor off
    pause space2         \ wait space2 time
  next b2               \ next loop

  pause 2000            \ stop motor for 2 seconds

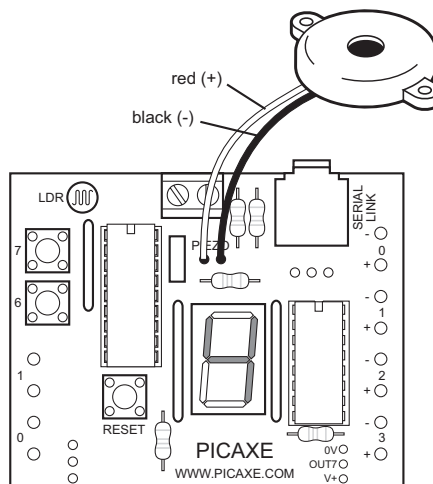
goto main

```

TUTORIAL 4 - BUZZERS AND PIEZO-SOUNDERS



Buzzers will make a noise when they are connected to a power supply. This noise is usually 'fixed' at one frequency and so buzzers can only make one 'tone'. Piezo-sounders use a different type of system to create noises, and can be used to create noises of different tones by providing them with a 'pulsed' output.



The PICAXE system can automatically create noises of different frequencies by use of the sound command.

```
main:
    sound 6,(50,100)      ' make a sound on 6, freq 50, length 100
    sound 6,(100,100)    ' make a sound on 6, freq 100, length 100
    sound 6,(120,100)    ' make a sound on 6, freq 120, length 100
    pause 1000           ' wait 1 second
    goto main            ' loop back to start
```

To test this program you must add a piezo sounder (not supplied, part number SPE002) to the tutorial board. To do this solder the red wire to the hole marked '+' and the black wire to the hole marked '-' under the word PIEZO in the centre of the board.

The first number provides the pin number (on the tutorial board output pin 6 is used). The next number is the tone, followed by the duration. The higher the tone number the higher pitch the sound (note that some sounders cannot produce very high tones and so number greater than 127 may not be heard).

The following program uses a for...next loop to produce 120 different sounds.

```
main:
  for b0 = 1 to 120      ' start a for...next loop
    sound 6, (b0,50)    ' make a sound on pin 6, freq value from
b0
  next b0                ' next loop

end
```

The number stored in variable b0 increase by 1 in every loop (1-2-3 etc.) Therefore by using the variable name b0 in the tone position, the note can be changed on each loop.

The following program does the same task but backwards.

```
main:
  for b0 = 120 to 1 step -1      ' start a for...next loop
(counting down)
    sound 6, (b0,50)    ' make a sound on pin 6, freq value from
b0
  next b0                ' next loop

end
```

This next program will give out all 256 possible sounds

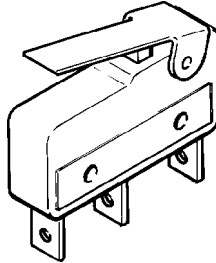
```
main:
  sound 6, (b0,50)    ' make a sound
  let b0 = b0 + 1    ' add 1 to the variable value
  goto main          ' loop again
```

In this case the program loops forever. However it is important to understand how the PICAXE performs mathematics.

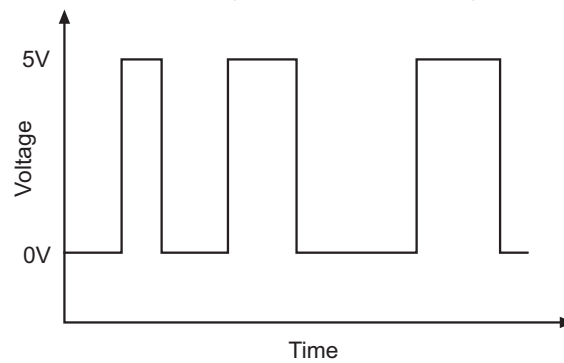
The PICAXE only understands byte numbers, that is whole numbers between 0 and 255. It cannot understand fractions and cannot work with negative numbers or numbers bigger than 255. Therefore if you try to add one to 255 the number will overflow back to 0. Therefore, in the program above, the value in variable b0 will go 252-253-254-255-0-1-2 etc. as the program loops.

TUTORIAL 5 – USING INPUTS

Digital Sensors

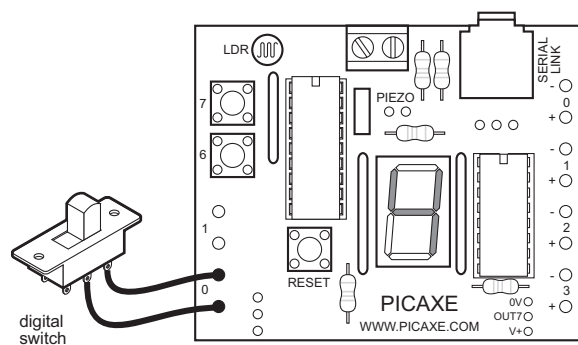


A digital sensor is a simple 'switch' type sensor that can only be 'on' or 'off'.



Common examples of a digital sensor are:

- microswitches
- push and rocker switches
- reed switches



The tutorial board has two push switches connected to inputs 6 and 7. Another two switches can be connected to the input positions 0 and 1 if desired.

This program below shows how to react to switch pushes. In this program output pin 7 flashes every time the push switch on input pin 6 is pushed.

```
main:                                ' make a label called 'main'
    if input6 is on then flash      ' jump if the input is on
    goto main                      ' else loop back around

flash:                               ' make a label called 'flash'
    high 7                         ' switch output 7 on
    pause 2000                     ' wait 2 seconds
    low 7                          ' switch output 7 off
    goto main                      ' jump back to start
```

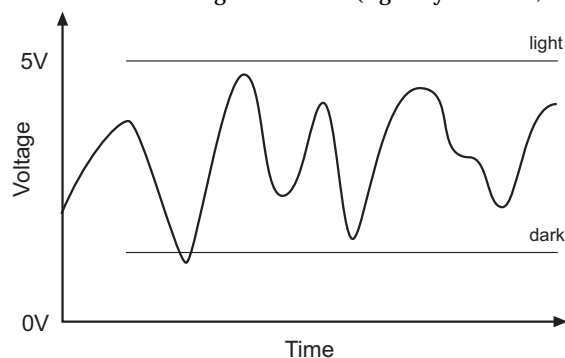
In this program the first three lines make up a continuous loop. If the input is off the program just loops around time and time again.

If the switch is then pushed the program jumps to the label called 'flash'. The program then flashes output 7 on for two seconds before returning to the main loop.

Note carefully the spelling in the if...then line – input6 is all one word (without a space). Note also that only the label is placed after the command then – no other words apart from a label are allowed.

Analogue Sensors

An analogue sensor measures a continuous signal such as light, temperature or position. The analogue sensor provides a varying voltage signal. This voltage signal can be represented by a number in the range 0 and 255 (e.g. very dark = 0, bright light = 255).



Common examples of analogue sensors are:

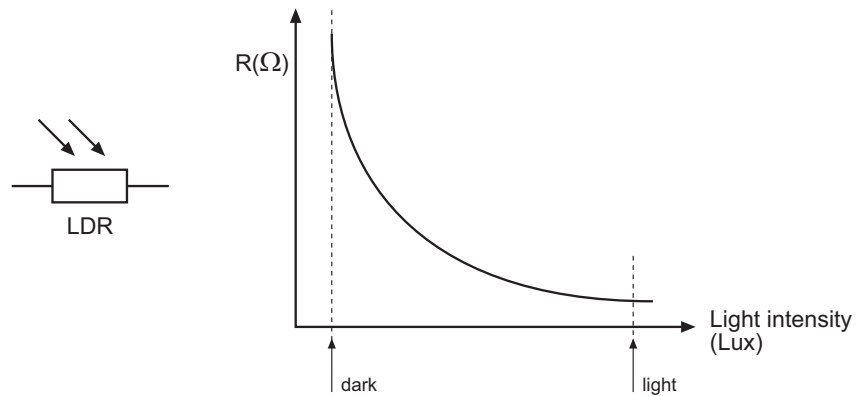
- LDR (Light Dependant Resistor)
- Thermistor
- Variable Resistor (potentiometer)

The tutorial board has an LDR mounted on the board, connected to input 2.

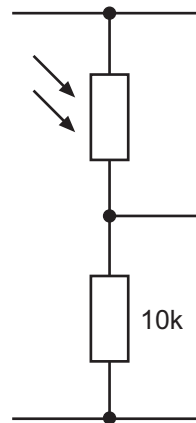
Light Dependent Resistor (LDR)

The LDR is a component whose resistance depends on the amount of light falling on it. Its resistance changes with light level. In bright light its resistance is low (typically around 1k). In darkness its resistance is high (typically around 1M).

The circuit symbol and a graph showing the resistance in various light levels are shown below:



The LDR sensor is connected to input 2 in a potential divider arrangement.



Reading Analogue Input Channels

The value of an analogue input can be easily copied into a variable by use of the 'readadc' command. The variable value (0 to 160) can then be tested. The following program switches on one LED if the value is greater than 120 and a different LED if the value is less than 70. If the value is between 70 and 120 both LEDs are switched off.

```
main:                                ' make a label called ,main
    readadc 2,b0                     ' read channel 2 into variable b0
    if b0 > 120 then top              ' if b0 > 120 then do top
    if b0 < 70 then bot               ' if b0 < 70 then do bot
    low 1                             ' else switch off 1
    low 2                             ' and switch off 2
    goto main                        ' jump back to the start

top:                                  ' make a label
    high 1                           ' switch on 1
    low 2                             ' switch off 2
    goto main                        ' jump back to start

bot:                                  ' make a label
    high 2                           ' switch on 2
    low 1                             ' switch off 1
    goto main                        ' jump back to start
```

Note that the PICAXE-18 microcontroller has 3 analogue channels labeled 0 to 2. On the tutorial board the LDR is connected to pin2 permanently, but you connect another sensor to inputs 0 or 1.

When using analogue sensors it is often necessary to calculate the 'threshold' value necessary for the program (ie the values 100 and 150 in the program above). The debug command provides an easy way to see the 'real-time' value of a sensor, so that the threshold value can be calculated by experimentation.

```
main:                                ' make a label called main
    readadc 2,b0                     ' read channel 2 into variable b0
    debug b0                         ' transmit value to computer screen
    pause 100                        ' short delay
    goto main                        ' jump back to the start
```

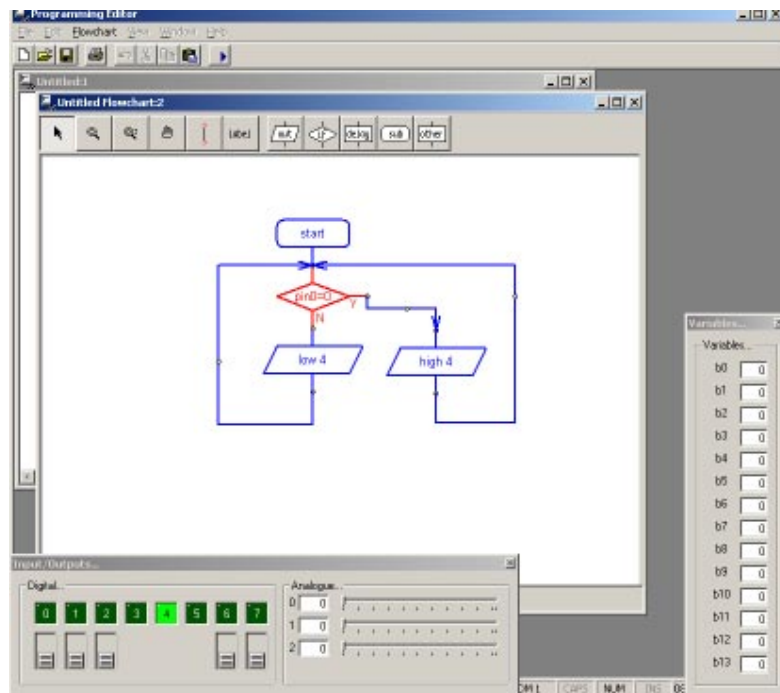
After this program is run a 'debug' window showing the value of variable b0 will appear on the computer screen. As the sensor is experimented with the variable value will show the current sensor reading.

TUTORIAL 6 – DRAWING FLOWCHARTS

Flowcharts are a useful tool that allows programs to be represented graphically to make them easier to understand. The Programming Editor software includes a flowchart editor that allows flowcharts to be drawn on screen. These flowcharts can then be converted to BASIC listings for download into the PICAXE. The flowcharts can also be printed or exported as graphics files for inclusion within project portfolios.

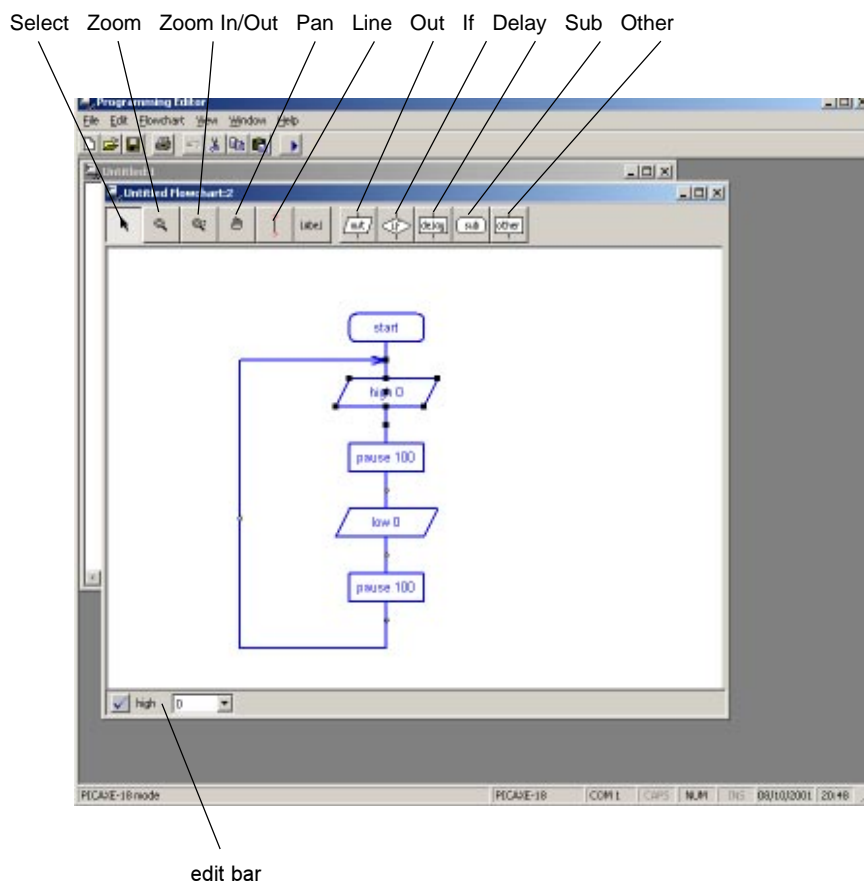
Detailed instructions:

1. Connect the PICAXE cable to the computer serial port. Note which port it is connected to (normally labelled COM1 or COM2).
2. Start the Programming Editor software.
3. Select View>Options to select the Options screen (this may automatically appear).
4. Click on the 'Mode' tab and select PICAXE-18
5. Click on the 'Serial Port' tab and select the serial port that the PICAXE cable is connected to. Click 'OK'
6. Start a new flowchart by clicking the File>New Flowchart menu.
7. Draw the flowchart shown below by dragging the correct symbols onto the screen, and then using the mouse to draw arrows between the symbols.
8. Once the flowchart is complete it can be converted into a BASIC program by selecting Flowchart>Convert Flowchart to BASIC. The BASIC program can then be downloaded to the PICAXE as normal.
9. To print or save the flowchart, use the File menu as normal. To export the flowchart as a graphic file, use the File>Export menu. To publish the image in a Word document select file type EMF. To publish the flowchart on an internet web page use the GIF file type.



The Flowchart Editor allows flowcharts to be drawn and simulated on-screen. The flowchart can then be automatically converted into a BASIC program for downloading into the microcontroller.

Flowchart Screen



Select Tool

Use this to select and move shapes. When a single shape is selected it's BASIC code can be edited in the edit bar at the bottom of the window.

Zoom

Use to zoom in to an area of the graph. Right click to zoom out.

Zoom In/Out

To zoom in click and move the mouse up. To zoom out click and move the mouse down.

Pan

Use this tool to move around the flowchart.

Line Tool

Use this tool to draw lines between shapes. Corners can be added by clicking once. When the line is near to a shape it will 'snap' to the connection point.

Label Tool

Use this tool to add descriptive labels or titles to the flowchart.

Out / If / Delay / Sub / Other

Click on these buttons to move to the command sub-menu to select commands.

Drawing Flowcharts

To draw a flowchart click on one of the command menu buttons (out / if / delay / sub / other) on the toolbar to move to the appropriate command sub-menu. Select the appropriate command and then click on the screen where the shape is required. Do not try to locate the shape precisely at first – just drop it in the general area and then use the select tool to move the shape to the correct position.

Once the shape is in position click on it so that it is highlighted. The BASIC code for the shape will then appear in the edit bar at the bottom of the screen. Edit the code as required, and then press the 'tick' button to save the changes.

For further information about each command see the 'BASIC Commands' help file. Note that some unique commands (e.g. servo for the PICAXE28) will only appear when the software is in the appropriate mode (View>Options menu).

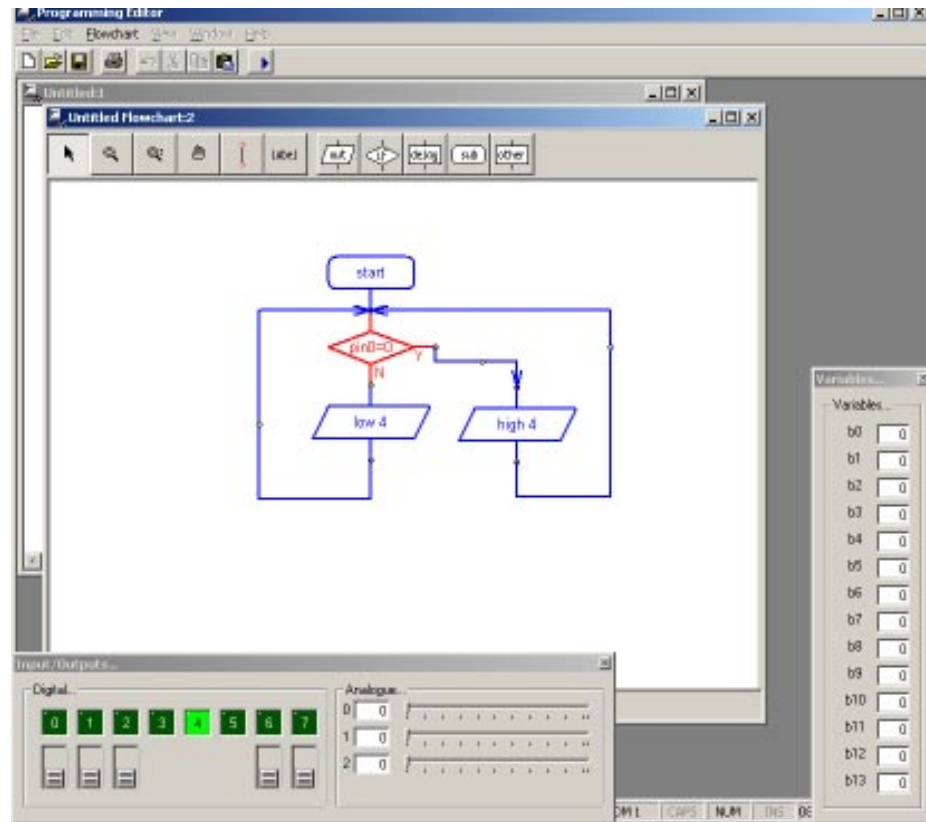
Joining Shapes

Shapes are joined by moving them close together until they 'snap' together. Alternately lines can be drawn between the shapes using the 'line tool' from the main toolbar. Note that it is only possible to join the bottom (side) of shapes to the top of other shapes. Only one line is allowed out of the bottom of each shape.

To enable neat diagrams, corners to the lines can be added by clicking with the mouse. When a line moves close to a connection point it will snap into position and then a click will finish the line.

Lines cannot be moved. If you try to move a line it will be deleted and a new line must be created.

On Screen Simulation



To simulate the flowchart, click 'Simulate' from the Flowchart menu. The program will then start to run on-screen.

As the program runs each cell is highlighted red as it is carried out. The 'Inputs/Outputs' and 'Variables' windows also appear when a simulation is being carried out. To adjust the input values click the on-screen switch or slide the analogue input slider.

The time delay between shapes can be adjusted via the Flowchart options (View>Options>Flowchart menu).

Note that certain commands have no on-screen simulation equivalent feature. In this case the command is simply ignored as the flowchart runs.

Downloading Flowcharts

Flowcharts are not directly downloaded to the microcontroller. First the flowchart is converted into a BASIC program, which is then downloaded.

To convert a program select 'Convert' from the Flowchart menu. The BASIC program for downloading will then be created.

Shapes that are not connected to the 'start' or 'sub' shapes in the flowchart are ignored when the conversion takes place. The conversion will stop if an unconnected shape is found. Therefore always use a 'stop' shape or line to complete the flowchart before simulation or conversion.

Note that it is possible to quickly convert and then download a flowchart by pressing the shortcut key <F5> twice.

Using Symbols

Inputs, Outputs and Variables can all be renamed using the 'Symbol Table' from the Flowchart menu. When a symbol is renamed the new name appears in the drop-down menus on the edit bar. Note that you should not use commands (e.g. switch or sound) as a symbol as this will generate errors in your converted BASIC program.

Saving and Printing Flowcharts

Flowcharts can be saved, printed and exported as graphic files (for adding to word processor documents) via the File menu. Flowcharts can also be copied to the Windows clipboard (for pasting into other applications) via the Edit menu.

TUTORIAL 7 - NUMBER SYSTEMS

A microcontroller operates by performing a large number of commands in a very short space of time by processing electronic signals. These signals are coded in the binary system – the signal either being high (1) and low (0)

The counting system used in everyday activities is the decimal system. This number system uses the ten familiar digits 0 to 9 to explain how big or small the number is.

However when working with microcontrollers it is sometimes easier to work in binary. This is especially true when trying to control multiple outputs at the same time.

A single binary digit is referred to a bit (binary digit). The PICAXE systems use 8 bits (1 byte), with the least significant bit (LBS) on the right hand side and the most significant bit (MSB), on the left hand side.

Therefore the binary number %11001000 means set bits 7,6,3 high (1) and the others low (0). The % sign tells the computer you are working in binary instead of decimal.

This means you can control all 8 outputs at the same time, instead of just using the high and low commands. The following program demonstrates how to make the seven segment display on the tutorial board count from 0 to 9.

```
main:
    let pins = %00111111    ' digit 0
    pause 250               ' wait 0.25 second
    let pins = %00000110    ' digit 1
    pause 250               ' wait 0.25 second
    let pins = %01011011    ' digit 2
    pause 250               ' wait 0.25 second
    let pins = %01001111    ' digit 3
    pause 250               ' wait 0.25 second
    let pins = %01100110    ' digit 4
    pause 250               ' wait 0.25 second
    let pins = %01101101    ' digit 5
    pause 250               ' wait 0.25 second
    let pins = %01111101    ' digit 6
    pause 250               ' wait 0.25 second
    let pins = %00000111    ' digit 7
    pause 250               ' wait 0.25 second
    let pins = %01111111    ' digit 8
    pause 250               ' wait 0.25 second
    let pins = %01101111    ' digit 9
    pause 250               ' wait 0.25 second
    goto main
```

Each 'let pins=' line changes the number of bars that are lit on the seven segment display. This is quicker than using lots of 'high' and 'low' commands.

Displaying Analogue Values on the Seven Segment Display

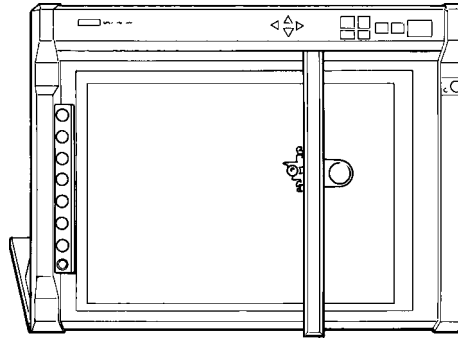
This program reads the light value from the LDR sensor on input 2 and then displays a value digit on the seven segment display.

```
main: readadc 2,b1          ' read analogue pin 2 into variable b1
    if b1 > 150 then show9 ' test variable b1 value and jump
    if b1 > 130 then show8
    if b1 > 110 then show7
    if b1 > 90 then show6
    if b1 > 70 then show5
    if b1 > 50 then show4
    if b1 > 30 then show3
    if b1 > 20 then show2
    if b1 > 10 then show1

show0:
    let pins = %00111111 ' digit 0
    goto main
show1:
    let pins = %00000110 ' digit 1
    goto main
show2:
    let pins = %01011011 ' digit 2
    goto main
show3:
    let pins = %01001111 ' digit 3
    goto main
show4:
    let pins = %01100110 ' digit 4
    goto main
show5:
    let pins = %01101101 ' digit 5
    goto main
show6:
    let pins = %01111101 ' digit 6
    goto main
show7:
    let pins = %00000111 ' digit 7
    goto main
show8:
    let pins = %01111111 ' digit 8
    goto main
show9:
    let pins = %01101111 ' digit 9
    goto main
```

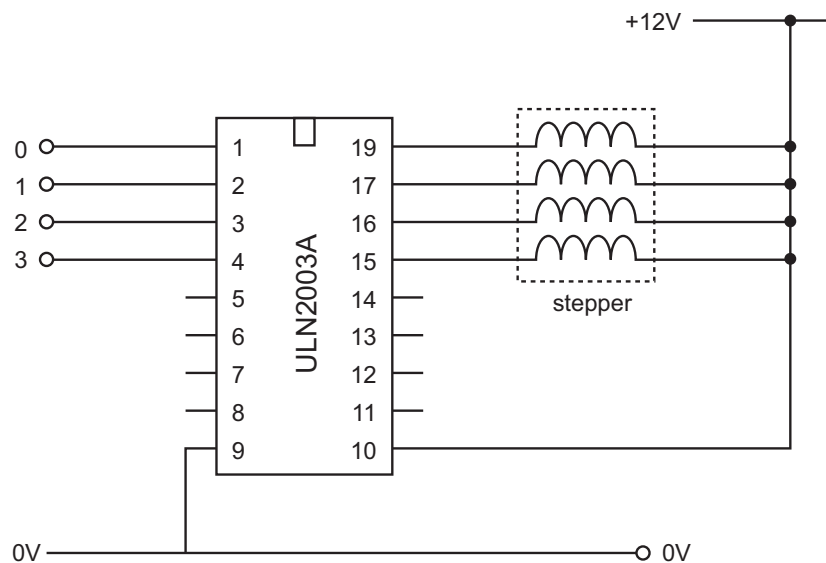
Controlling Stepper Motors

Stepper motors are very accurate motors that are commonly used in computer disk drives, printers, XY plotters and clocks. Unlike dc motors, which spin round freely when power is applied, stepper motors require that their power supply is continuously 'pulsed' in four different patterns. For each pulse, the stepper motor moves around one 'step', typically 7.5 degrees (giving 48 steps in a full revolution).

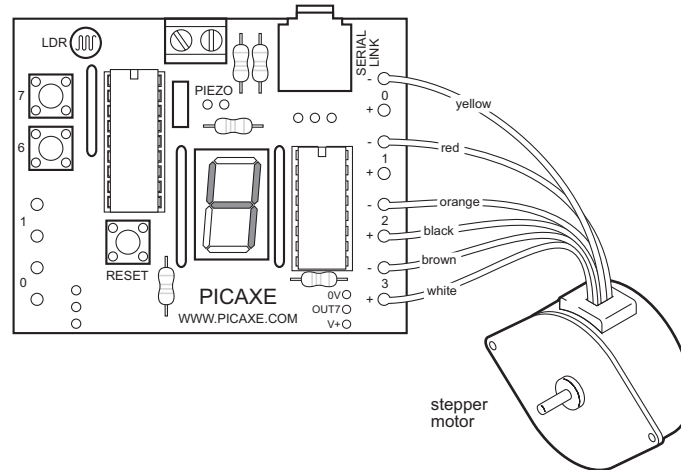


Stepper motors do have some limitations. First, the power consumption is greatest when the stepper motor is stopped (as all coils are still energised). The speed of revolution is also limited to around 100 steps per second, which provides a rotational speed of 2 rev / s or 120 rev / min.

The stepper motor contains magnets which are fixed to the central armature. Four electronic coils are located around the casing. When a current is passed through these coils they generate a magnetic field, which attract/repels the permanent magnets on the armature, and so the armature spins one 'step' until the magnetic fields align. The coils are then energised in a different pattern to create a different magnetic field, and the armature spins another step.



To make the armature rotate continuously the four coils inside the stepper motor must be switched on and off in a certain step order. The ULN2003A driver chip on the tutorial board provides the method of interfacing these four coils.



The stepper motor should be connected to the holes on the tutorial board as follows:

Black Wire	2 +
White Wire	3 +
Yellow Wire	0 -
Red Wire	1 -
Orange Wire	2 -
Brown wire	3 -

The table below show the four different steps required to make the motor turn

Step	Coil 4 (Output 3)	Coil 3 (Output 2)	Coil 2 (Output 1)	Coil 1 (Output 0)
1	1	0	1	0
2	1	0	0	1
3	0	1	0	1
4	0	1	1	0
1	1	0	1	0

To make the motor spin the other way the steps are reversed (i.e. 4-3-2-1-4 etc. rather than 1-2-3-4-1 etc.).

Note:

The wiring configuration of stepper motors varies from different manufacturers. Therefore, it may be necessary to rearrange the coil connections for the above sequence to operate correctly. An incorrect coil arrangement will result in the stepper motor vibrating back and forth rather than rotating. Most stepper motors are designed to work at 12V, but will generally work (with reduced torque) at 6V.

This program can also use a binary number that switches all of the output lines on and off at the same time. The binary output number for each step is shown in the table below:

Step	Binary Output
1	%00001010
2	%00001001
3	%00000101
4	%00000110
1	%00001010

Try changing the speed by altering the value of delay in the following program.

```

symbol delay = b0           ` define the variable
    let delay = 100         ` set delay to 0.1s

main: let pins = %00001010   ` first step
    pause delay             ` pause for delay
    let pins = %00001001    ` next step
    pause delay             ` pause for delay
    let pins = %00000101    ` next step
    pause delay             ` pause for delay
    let pins = %00000110    ` next step
    pause delay             ` pause for delay
    goto main               ` loop forever

```

TUTORIAL 8 - SUB-PROCEDURES

A sub-procedure is a separate 'mini-program' that can be called from the main program. Once the sub-procedure has been carried out the main program continues.

Sub-procedures are often used to separate the program into small sections to make it easier to understand. Sub-procedures that complete common tasks can also be copied from program to program to save time.

The following program uses two sub-procedures to separate the two main sections of the program ('flash' and 'noise').

```

symbol dp = 7           \ rename output7 'dp'
symbol buzzer = 6       \ rename output6 'buzzer'
symbol counter = b0     \ define a counter using variable b0

main:                   \ make a label called 'main'
    gosub flash         \ call the sub-procedure flash
    gosub noise         \ call the sub-procedure noise
    goto main           \ loop back

                        \ end of the main program
end

flash:                  \ make a sub-procedure called flash
    for counter = 1 to 25 \ start a for...next loop
        high dp         \ LED on
        pause 50        \ wait 0.05 second
        low dp          \ LED off
        pause 50        \ wait 0.05 second
    next counter        \ next loop
    return              \ return from the sub-procedure

noise:
    high buzzer         \ buzzer on
    pause 2000          \ wait 2 seconds
    low buzzer          \ buzzer off
    return              \ return from the sub-procedure

```

This second program shows how a variable can be used to transfer information into a sub-procedure. In this case variable b2 is used to tell the microcontroller to flash 5, and then 15, times.

```

symbol dp = 7           ' rename output7 'dp'
symbol counter = b0      ' define a counter using variable b0

main:                    ' make a label called 'main'
    let b2 = 5           ' preload b2 with 5
    gosub flash           ' call the sub-procedure flash
    pause 500             ' wait a while
    let b2 = 15           ' preload b2 with 15
    gosub flash           ' call the sub-procedure flash
    pause 500             ' wait a while
    goto main             ' loop back

end                       ' end of the main program

flash:                   ' make a sub-procedure called flash
    for counter = 1 to b2 ' start a for...next loop
        high dp           ' LED on
        pause 250         ' wait 0.25 second
        low dp            ' LED off
        pause 250         ' wait 0.25 second
    next counter          ' next loop
    return                ' return from the sub-procedure

```

Where next?

By completing these tutorials you have learnt all the basics about the PICAXE system – how to setup the system, how to develop programs, how to draw flowcharts and how to connect input and output devices. On the CDROM there are also some other very useful reference guides which will provide you with further information.

Exemplar Projects

The next reference point should be the exemplar projects, which give real life examples of how the PICAXE system can be used in the real world. Each project provides a sample circuit diagram and program listing, which may be copied or altered to meet your project requirements.

BASIC Command Guide

The BASIC language used by the PICAXE has over 30 commands, of which we have only used a few in this tutorial. Have a look through the other commands available, each command has a small program to demonstrate how it can be used within a project.

Interfacing Electronics Guide

This guide explains how to 'interface' a large number of input and output devices to the PICAXE microcontroller. If you want to know how to connect a buzzer, motor, solenoid or LDR to the PICAXE, the answer is here!

Finally all the latest information, and a technical support forum, are available on the internet at www.picaxe.co.uk

GOOD LUCK WITH YOUR PICAXE PROJECT!

APPENDIX 1: EQUIPMENT REQUIRED

All equipment can be purchased from the online store at

www.tech-supplies.co.uk

See the *Educational Systems>PICAXE* section for details on the PICAXE parts.

Equipment Required for tutorials within this booklet:

PICAXE18 Tutorial Board Pack (AXE050)

4 x AA batteries (BAT002)

Optional Connectors:

3 x 4pole screw terminal block (CON005)

Optional Output Devices:

SPE002 Piezo Sounder

GBX007 Solar DC Motor

GBX008 Unipolar Stepper Motor

APPENDIX 2: CROCODILE TECHNOLOGY

The Crocodile Technology software, by Crocodile Clips Ltd, allows students to build and test microcontroller circuits via on-screen simulations. In addition programs can be generated via flowcharts and then downloaded directly to the microcontroller.

A demo version of the software is available on the CDROM.

Compatibility:

You must be running version 1.52 Build 428 (or greater) to use the PICAXE system. If you are using an older version of Crocodile Technology please download the free upgrade from www.crocodile-clips.com. The software version can be found from the Help >About Crocodile Technology menu.

The latest PICAXE plugin for Crocodile Technology can be downloaded from www.tech-supplies.co.uk (Software>Crocodile Technology section).

Version 1.52 of Crocodile Technology supports the PICAXE-28, and has limited support for the PICAXE-18. It is expected that later releases of Crocodile Technology will have full-support for the PICAXE-18.

V1.52 restrictions for the PICAXE-28.
None.

V1.52 restrictions for the PICAXE-18:

1. Only digital inputs 0-2 are supported. Inputs 6 and 7 cannot be used.
2. Input 3 appears on screen, although it is not present on the PICAXE-18. Therefore this input must not be used within a simulation.
3. The analogue capabilities of the PICAXE-18 are not supported.

Configuring Crocodile Technology:

Before drawing a circuit or flowchart, it is recommended that the PICAXE system is configured via the Options>Programmer menu.

From the 'Options' menu, select 'Programmer'.

For the Programmer	select 'PICAXE'.
For the COM Port	select 'COM1' or 'COM2' as appropriate.
For the Default Class	select '18pin PIC' for PICAXE-18 select '28pin PIC' for PICAXE-28

The Target microcontroller settings are not used and may be left at the default settings.