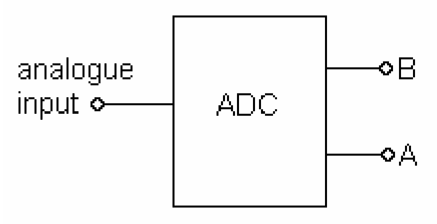
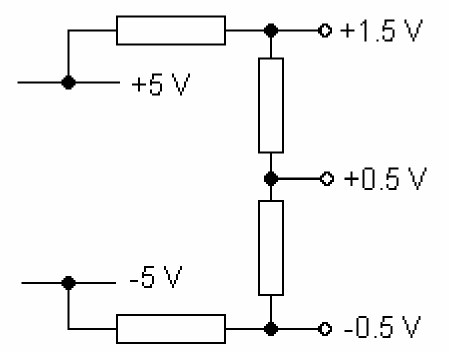
Flash converter

You are going to design a two-bit flash conversion analogue-to-digital converter which behaves as shown in the table.

input voltage range	output BA
+1.5 V to +2.5 V	10
+0.5 V to +1.5 V	01
-0.5 V to +0.5 V	00
-1.5 V to -0.5 V	11



1 Start off by assembling a resistor ladder to generate the three reference voltages shown.

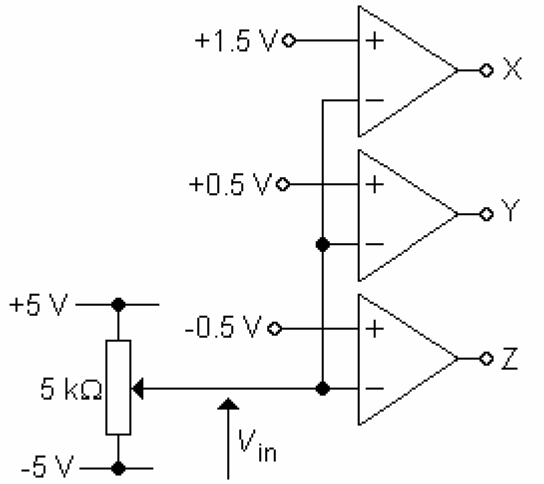


2 Use a voltmeter to test the outputs of the resistor ladder.

3 Add the op-amp chain and source of input voltage as shown below.

4 Use a voltmeter to help you complete this table. Use only the symbols **+** or **-**.

input voltage range	X	Y	Z
+1.5 V to +2.5 V			
+0.5 V to +1.5 V			
-0.5 V to +0.5 V			
-1.5 V to -0.5 V			



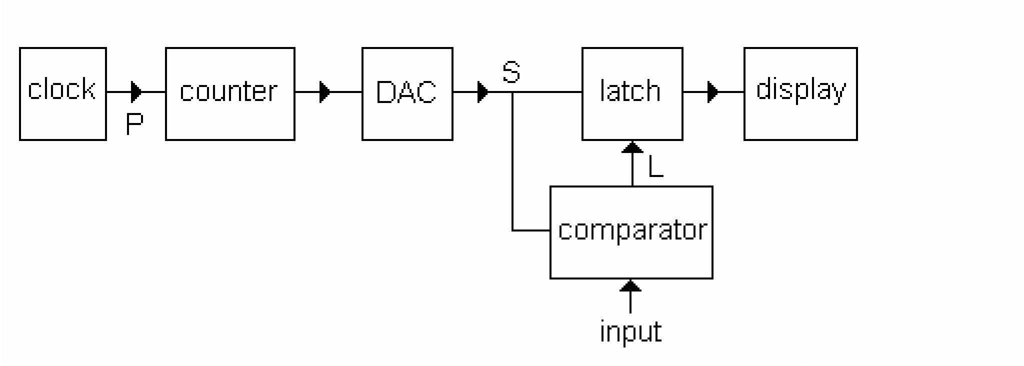
5 Now design the logic system to convert the signals at X, Y and Z into the ones required for the ADC. You should bear in mind that a 10 kΩ resistor is needed between an op-amp output and a logic gate input. You will need four EOR gates and two OR gates.

6 Assemble the logic system and add it to the op-amp chain. Verify that the whole system behaves as required.

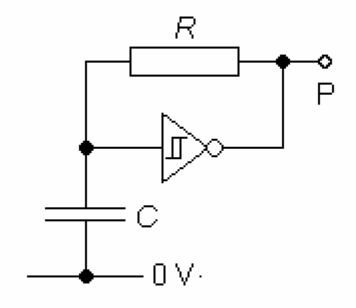
7 If you have time, extend the system so that it has twice as many levels in the same range, following the same style of coding (two's complement from 111 to 011).

Slope conversion

You are going to assemble and test a four-bit ADC which uses slope conversion to continuously sample an input signal. Here is the block diagram.

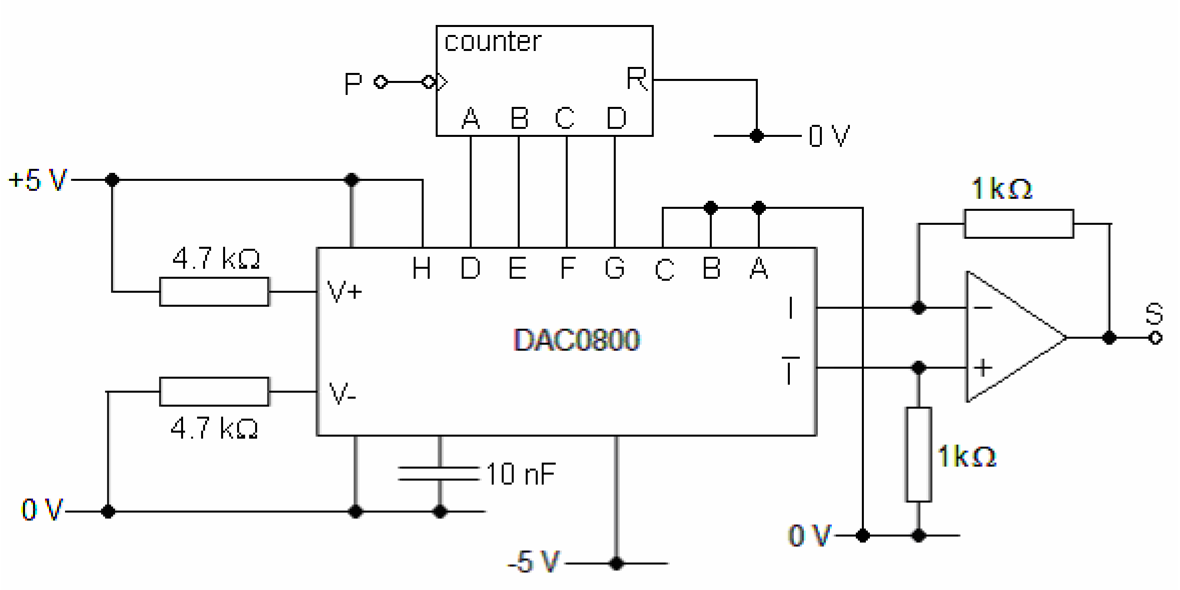


1 The clock is a free-running relaxation oscillator with a frequency of about 1 Hz. Select suitable component values for *R* and *C*. Use a voltmeter to check that the oscillator behaves as required.

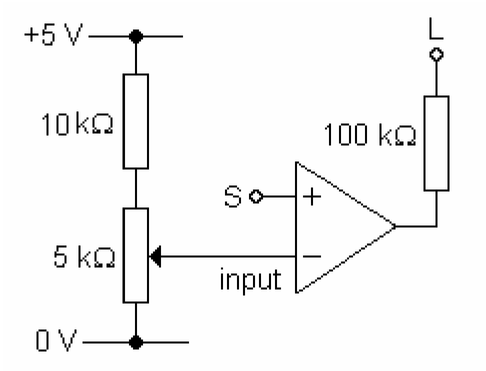


2 Add a four-bit counter. Check that it works correctly.

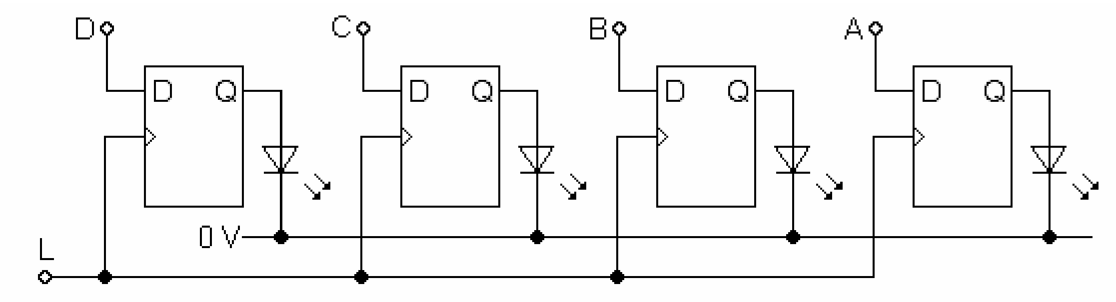
3 The DAC shown below should produce a voltage at A which ramps up in 16 steps from 0 V to 1 V. Connect it to the counter as shown, and use the voltmeter to verify that it operates as specified.



4 Now add a potentiometer to generate an analogue input signal and an op-amp to compare it with the DAC output signal S. Verify that the signal at L goes high every time that S goes above the voltage at the input.



5 The last stage is the four-bit latch and display shown below.



6 Complete this table for the working system.

input signal	DCBA
	0001
	0010
	0011
	0100
	0101
	0110
	0111
	1000
	1001
	1010
	1011
	1100
	1101
	1110
	1111

7 The conversion time for the system is about 16 s. By altering the frequency of the relaxation oscillator, use trial-and-error to establish the smallest conversion time for the system.

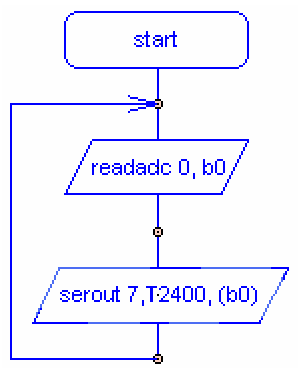
8 If you have time, adapt the system so that it produces a four-bit word which codes for input signals which have voltages between -1 V and +1 V.

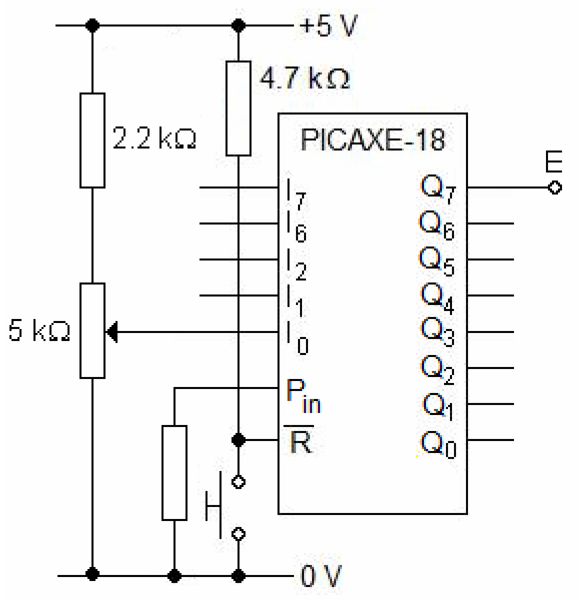
Serial output ADC

You are going to investigate the ADC inside a PICAXE-18 i.c.

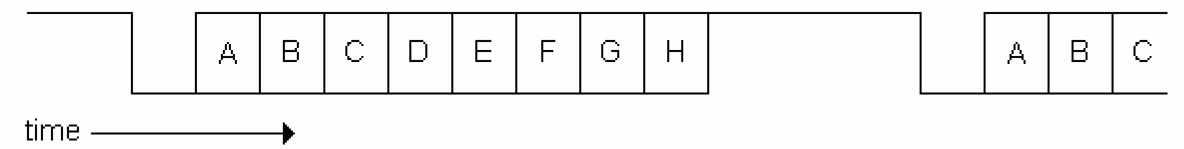
1 Set up the PICAXE-18 as shown opposite.

2 Download this flowchart into the PIC. It makes Q_7 transmit the eight-bit word from the ADC at I_0 in serial form.





3 Use an oscilloscope to study the signal at E. Set the timebase to 0.5 ms/ div and trigger on the falling edge of the signal. The signal should be a 0, followed by eight bits which can be 0 or 1, followed by a 1, and then repeated, as shown below.



4 Verify that the word HGFEDCBA changes as you alter the setting of the potentiometer. There are 16 different words, starting at 0000 0000 and ending at 1010 0000.

5 Measure the duration of the 0 which starts each word. This should allow you to determine the states of the individual bits in each word displayed on the oscilloscope screen.

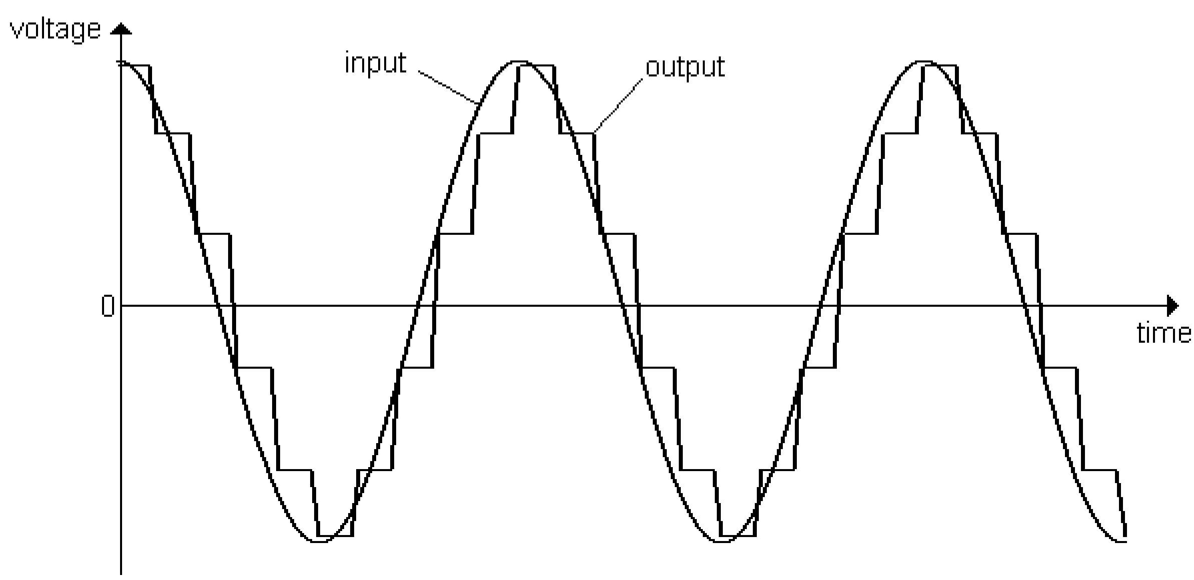
6 Connect a voltmeter to I_0. Start of with I_0 at 0.00 V and increase it slowly until the output word no longer changes. This should give you the range of the ADC.

7 Now try to measure the smallest voltage change at the input which causes a change in the output word. This gives you the resolution of the ADC.

8 Use the duration of the start of the high signal between the end of one word and the 0 preceding the next one to estimate the conversion time of the ADC.

Sampling distortion

You are going to use the spreadsheet SAMPLE.XLS to view the consequences of recreating an analogue signal which has been sampled by an analogue-to-digital converter. Here is a typical example of such a signal.



1 Open up the spreadsheet. In the top left-hand corner, enter a signal with an amplitude of 800 mV and a frequency of 250 Hz. Sample it with 16-bit words at a rate of 32 000 Hz.

2 Press F9 to update the calculations. Then compare the red output waveform with the green input waveform.

3 Find out what happens to the output waveform when the word length is reduced to 14-bit, 12-bit, 10-bit, 8-bit, 6-bit, 4-bit and 2-bit in turn. You will appreciate the changes best if you press F9 whilst looking at the waveforms.

4 The range of the converter is a fixed 2 000 mV. Calculate the resolution of the converter when it uses a 3-bit word. Confirm your value by finding, by trial-and-error, the smallest amplitude of input signal which gives a non-zero output waveform.

5 Repeat step 4 for a 6-bit word.

6 Set the word length to a fixed 8 bits. See what happens to the output waveform when the sampling frequency of 32000 Hz is halved to 16 000 Hz. Keep halving the sampling frequency until the input and output waveforms no longer have the same frequency.

7 Verify that the sampling frequency always has to be at least twice the signal frequency for error-free transmission of the signal frequency.