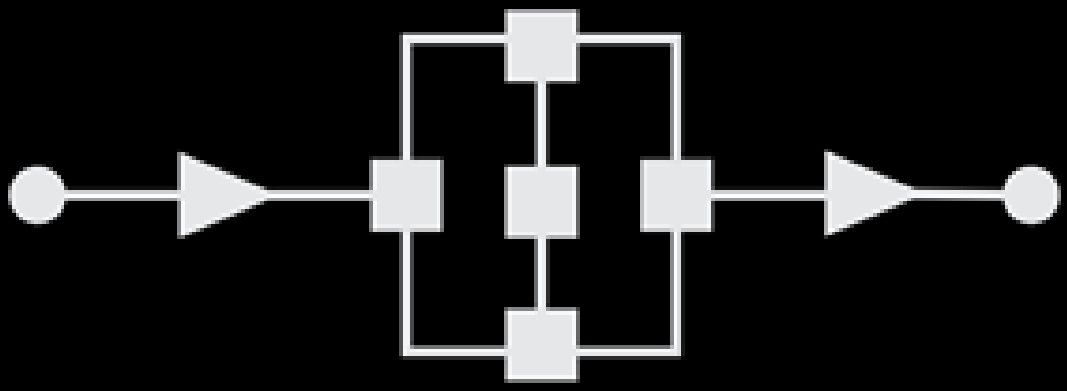
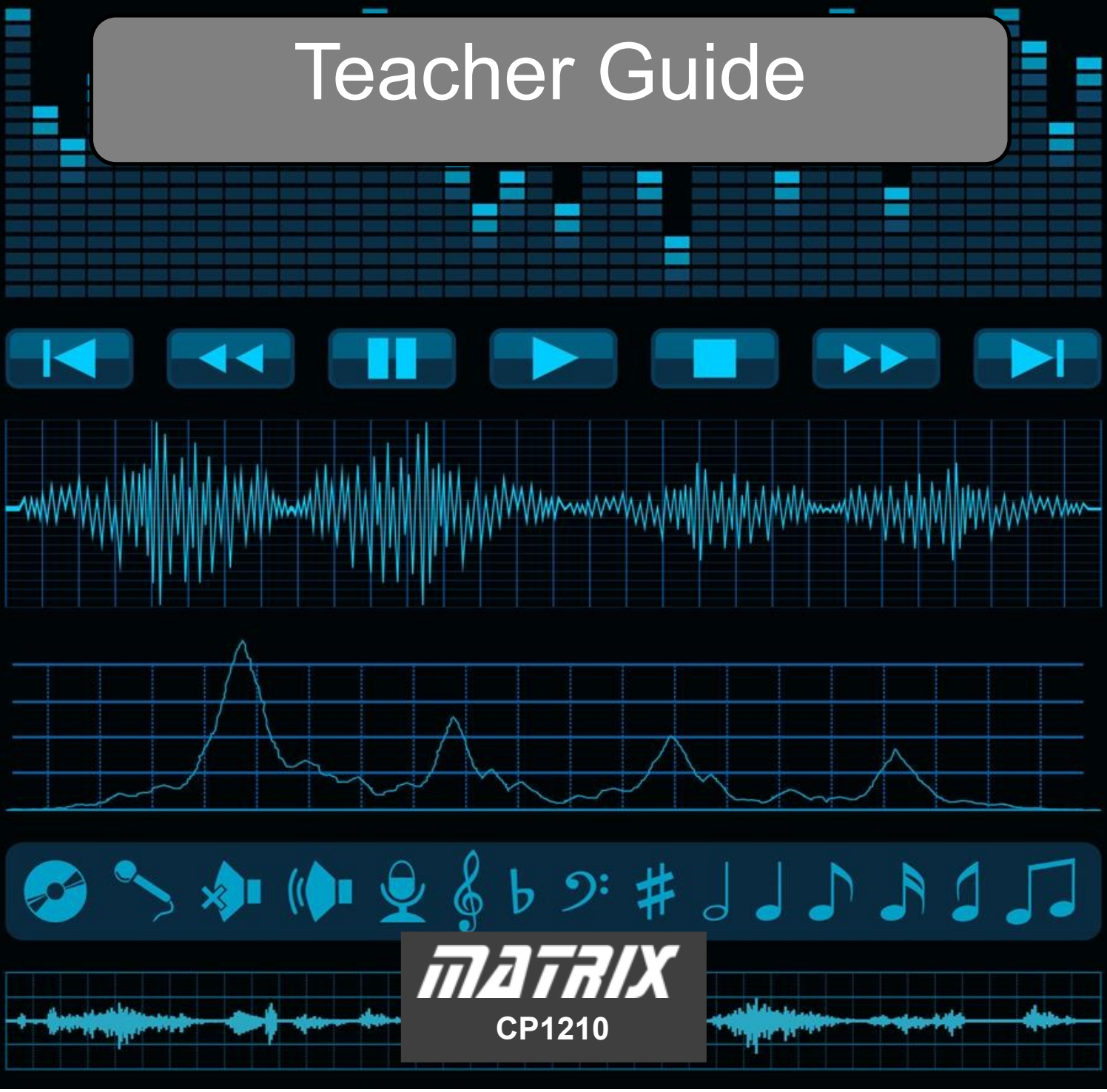


Sysblocks

Music with microcontrollers

Teacher Guide



MATRIX

CP1210

Teacher’s notes

Learning objectives

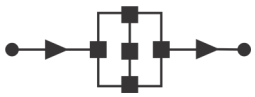
On successful completion of this course, the student will be able to:

- explain the significance of the terms ‘macro’ and ‘component macro’;
- describe the following techniques:
  - Analogue-to-digital conversion;
  - Digital-to-analogue conversion;
- create a ‘heartbeat’ flashing LED to show that the program is running;
- describe what happens when a programming interrupt is called;
- create and configure a timer interrupt;
- use an oscilloscope to observe the waveform of a signal;
- create and control the timing of an electronic ‘echo’;
- control the frequency spectrum of an audio signal using a filter;
- distinguish between the behaviour of a low-pass, a band-pass and a high-pass filter;
- explain why a piano, playing ‘middle C’, sounds different to a violin playing ‘middle C’;
- configure a summing block;
- use iterative techniques to produce a repeating echo;
- modify a program so that the amplitude of repeated echos dies away progressively;
- explain what is meant by reverberation;
- describe the function of an audio mixing desk;
- draw a block diagram of an audio mixing desk;
- describe the function of an audio equaliser;
- describe what is meant by sampling and sample-rate;
- relate the significance of sample-rate and signal frequency.

Teacher's notes

	Notes
Worksheet 1	Concepts involved: microprocessor, graphical programming structure, macro The amount of support needed here and the time allocated depends on the previous experience of the students. For some, an initial 'walk-through' the Flowcode 10 screen, identifying various menus and translating jargon would be helpful. Introducing the 'Flowcode Wiki' is one way to do this. The focus is on the 'main' program, the core around which the rest is built. The worksheet gives step-by-step instructions as to how to create it. As this is used in many of the following programs, it is well-worth spending time going through each element of this in detail. The Flowcode screen can be divided into a number of sections, including the 2D panel, where icons representing hardware are placed and the programming workspace. 'Double-clicking' on hardware icons and on command icons in the flowchart opens up panels allowing their properties to be selected. Students should be shown how to 'debug' the program as a way to check that the program works. They will need access to storage in order to save and later access their programs. Matrix have made available copies of all programs used in the course.
Worksheet 2 **In and Out**	Concepts involved: analogue, digital ports, interrupt It is important that students grasp the significance of the table given on the first page of the worksheet, detailing the connections between the outside world and the microprocessor. The instructor could create a wallchart with this information, or a student handout as this information is required throughout the course. For some students, an explanation of the programming concept of an interrupt may be needed. In the case of this program, it is simply a timing mechanism. The internal clock 'Timer 1' calls the 'UserMacro' routine periodically, (every time it 'overflows'). The instructions refer to the use of the 'Picoscope', a digital oscilloscope. Some colleges will prefer to use alternative devices. Either way, it may be necessary to acquaint / remind students how to use the equipment. Although the instructions ask students to plug in either headphones or speakers, in practice, headphones may be preferable to having a lab. full of sound from an array of speakers!

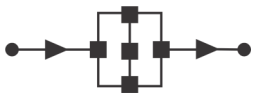
Teacher's notes



Music with microcontrollers

	Notes
Worksheet 3 **The 'Click' generator**	The big difference between this and the previous program is the input device used. In program 1, an external source, such as the 'AWG' on a 'Picoscope' device was used to generate a signal via an input connector. In this case, the signal is generated internally. Once again, this is a core program that will be re-visited and extended later. Instructors could distinguish between 'byte' and 'string' data types and may choose to explain the role of the Decision components in the program. They could point out that a short-lived burst of sinusoids will sound to the human ear as a 'click'.
Worksheet 4 **Control the Output**	Concepts involved: amplitude, volume This program is a development of program 1, the 'In and Out' program. The input is generated externally from a source such as a 'Picoscope AWG'. A second output port, connected via a 'Scale' block, is used to demonstrate the effect of controlling the output. The original output port is unaffected. This difference should be apparent when students listen to each output channel separately or study the traces on the oscilloscope. The effect of the 'Scale' block depends on the 'Initial Integer Scaler' value. This is the focus of the 'Challenge'. Students could explore the other settings on the 'Scale' block, such as the 'Scale Type'.
Worksheet 5 **Control the Tone**	Concepts involved: tone, frequency spectrum, types of filter This program follows a similar pattern to the previous one except that the DSP Scale block is replaced by a DSP Filter block, configured to be a low-pass filter with a 'Coefficient 0' set to '10. Testing follows the same pattern as for the previous program. Again, it can be instructive to listen to each output channel separately, if possible. The 'Challenge' looks at the effect of changing the filter's configuration parameters.

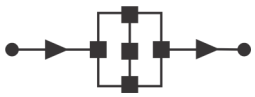
Teacher's notes



Music with microcontrollers

	Notes
Worksheet 6 **Anatomy of an Echo**	This program generates an artificial echo by adding together the 'click' from the system tested in program 2 and a delayed version of the same signal. As a result, every 'click' produces two copies, one following shortly after the other. The 'Challenge' invites students to change the delay by varying the 'Delay Count' properties. Using a 'click' produces a clearer echo, though students are encouraged, in the 'Challenge' to observe what happens when music is used as the input (through an 'InputADC' block. Addition is carried out by a DSP Math block, (which can also subtract, multiply, divide and carry out a range of other mathematical operations.) Students could explore the effect of using other mathematical operations.
Worksheet 7 **Multiple Echoes**	This program incorporates DSP blocks from the previous three programs to produce a (theoretically infinite) series of echoes using an iterative process. It is tested in the same way as the preceding program. The 'Challenge' combines activities from the three previous programs.
Worksheet 8 **Reverberation**	This takes the process used in program 5 one stage further, using three delay blocks to produce three copies of the original 'click'. These are combined using a DSP Adder block. The combined signal is then fed to the Math block as before. By this stage in the course, the instructions are deliberately becoming less granular, leaving more for the students to work out for themselves. Where there are problems, they could be shown the 'official' version of the program.

Teacher's notes



Music with microcontrollers

	Notes
Worksheet 9 **Mixing signals**	This program explores a common task in music technology - combining together signals from a variety of sources. The instructor could demonstrate a commercial mixing desk to introduce this topic, pointing out the various controls that the desk offers. Initially, the inputs are generated internally using DSP 'Wavegenerator' blocks. This delivers tighter control than using relatively random music signals. The three inputs are combined using a DSP 'Adder'. The 'desk' uses the two encoders to select input and assign a gain value to it. Their appetite whetted, students are invited to experiment with a larger scale mixing desk, which incorporates the ability to input several music streams.
Worksheet 10 **Equalisation**	Concepts involved: equalisation Equalisation is a more comprehensive form of tone control. The instructor could expand on what equalisation means and give practical examples. This system uses what, by now, should be familiar components and testing scheme. It offers few instructions but gives the students sufficient information for them to create the program. Again, where there are problems, they could be shown the 'official' version of the program.
Worksheet 11 **Sampling**	Concepts involved: sampling, sample rate, Nyquist's theorem This topic is central to the task of creating quality music files. In analogue recording, the entire audio wave is used to create the file. In digital audio, the input signal is sampled periodically. Put simply, its signal voltage is measured from time to time and is converted to a digital numbers which are stored in the file. The rate at which these measurements are taken determines the quality of the recording. The frequency of the sounds being recorded also has an influence on this. This leads to the Nyquist sampling theorem

Teacher’s notes

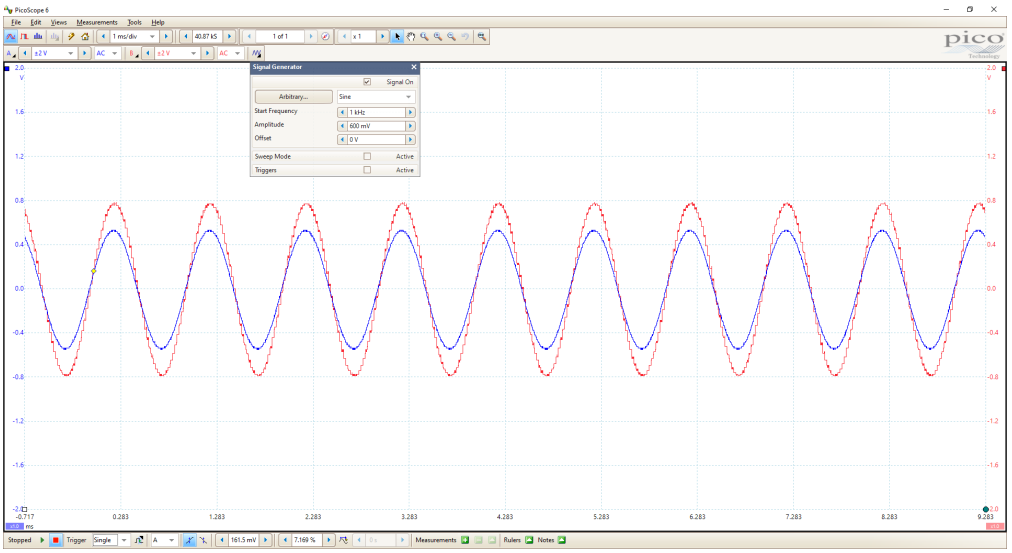
	Notes
Beyond this course	Instructors may wish to incorporate additional worksheets from the ‘Systems and Signals’ course.

Results

Results

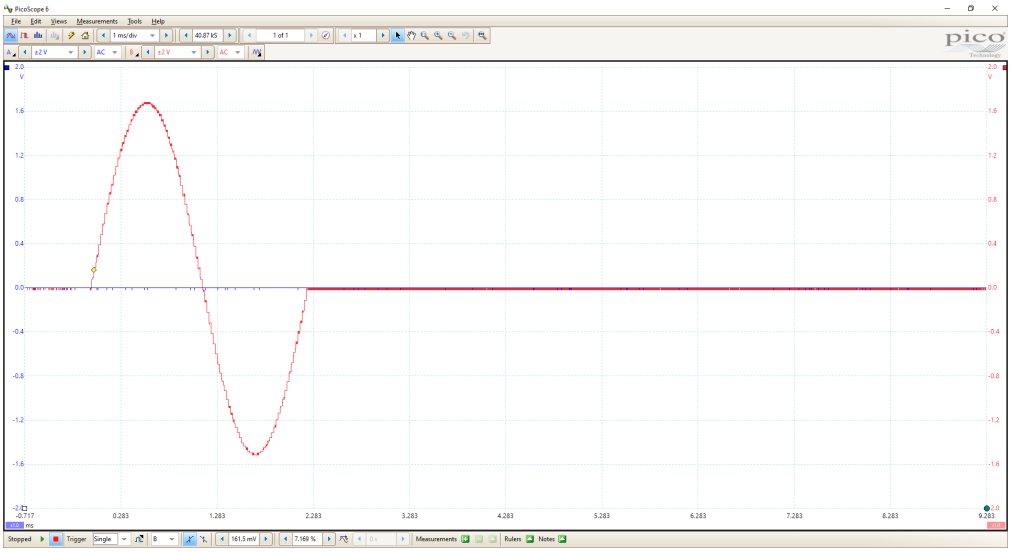
Worksheet 2 - in and out

blue = input signal
Red = output signal



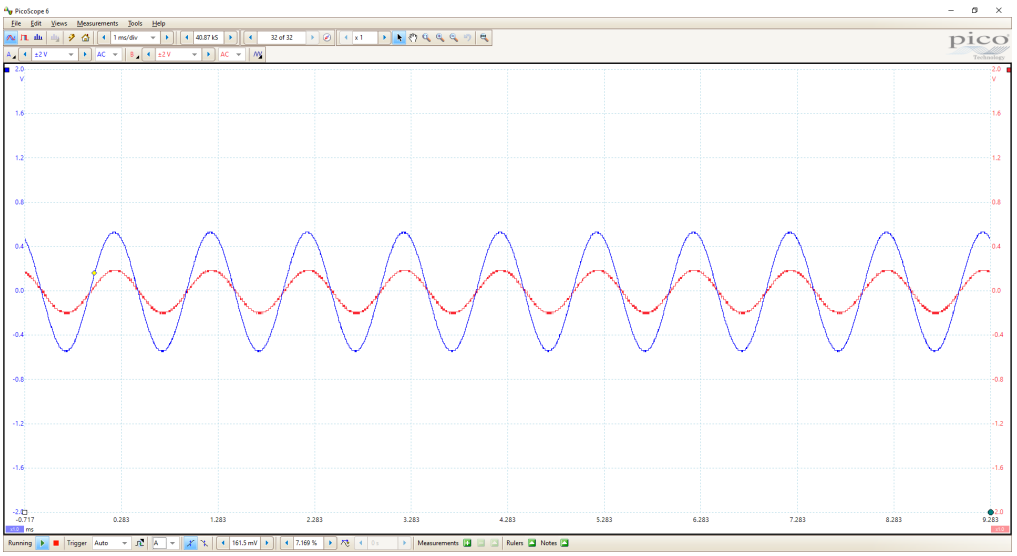
Worksheet 3 - click generator

Red = output signal



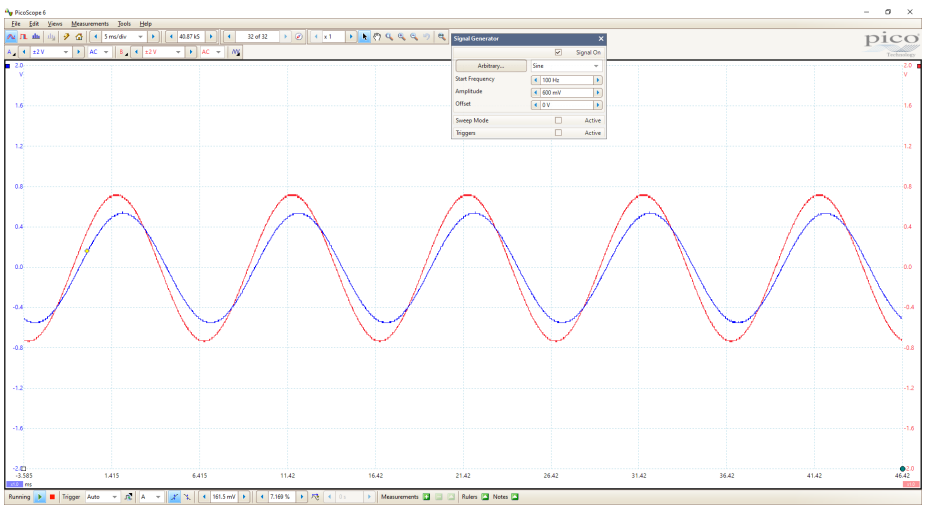
Worksheet 4 - control the output

blue = generated signal
Red = signal / 4



Results

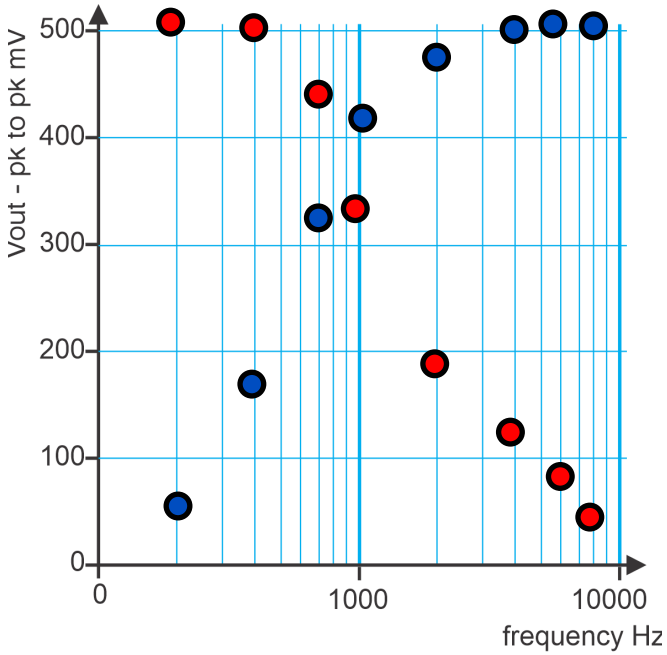
Worksheet 5 - control the tone



blue = input signal
Red = output signal

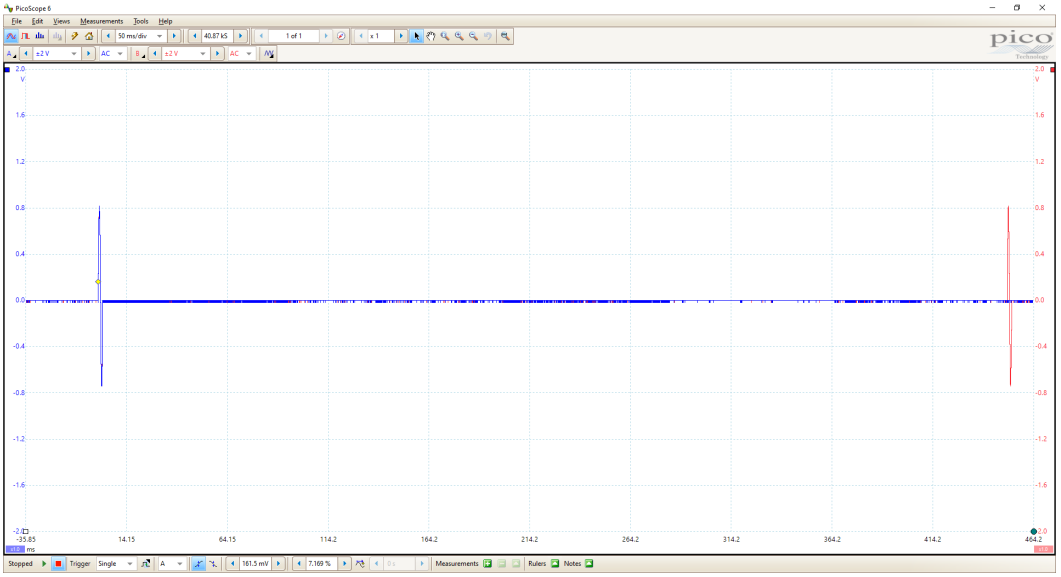
Note the phase shift

f Hz	Low pass mV	High pass mV
100	511	63
300	505	192
600	425	325
1000	326	416
2000	190	487
3000	131	503
5000	80	510
8000	50	510



Worksheet 6 - anatomy of an echo

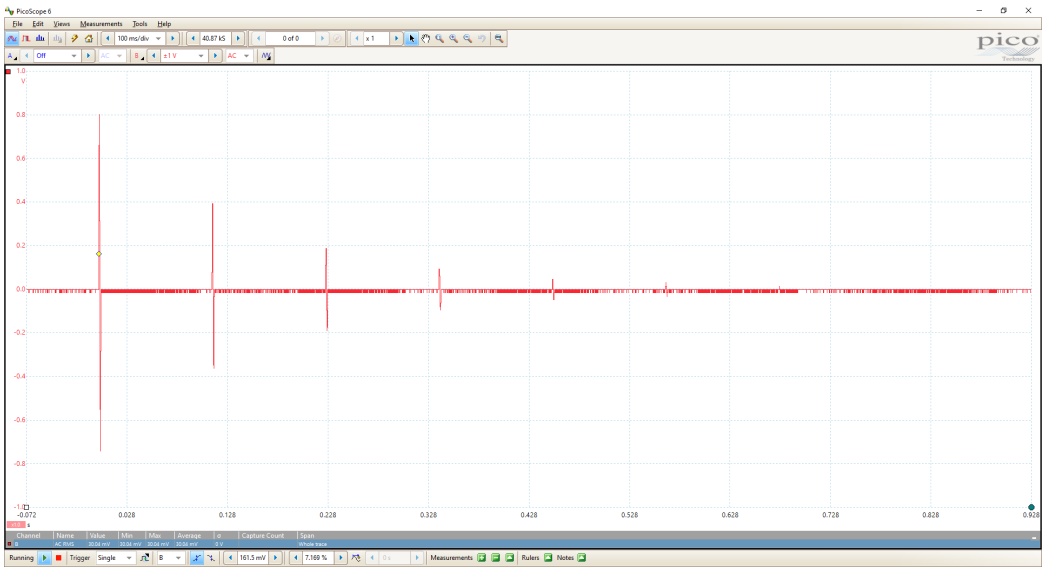
Blue = initial signal
Red = echoed signal



Results

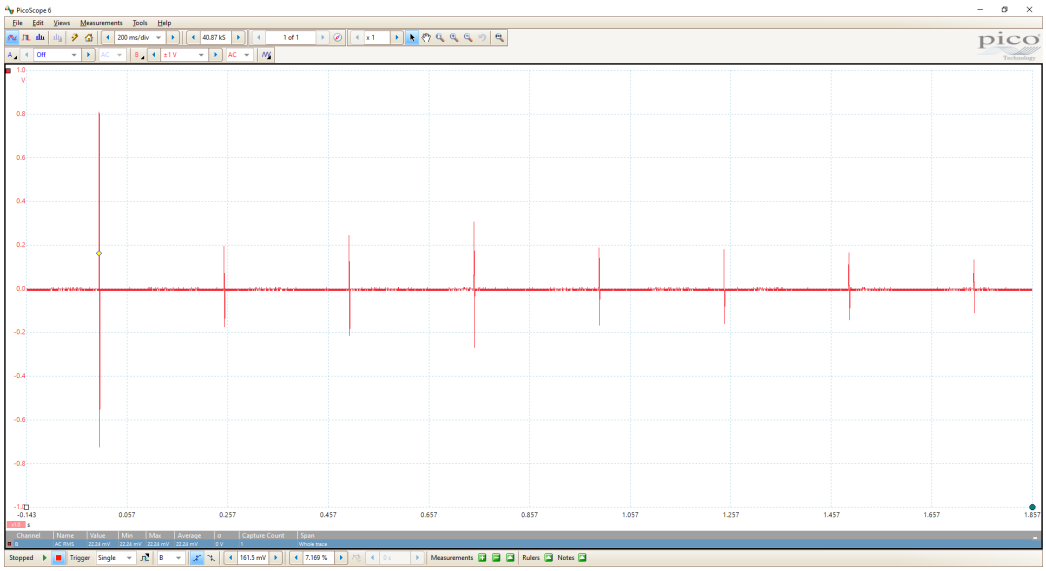
Worksheet 7- multiple echoes

Red = output signal

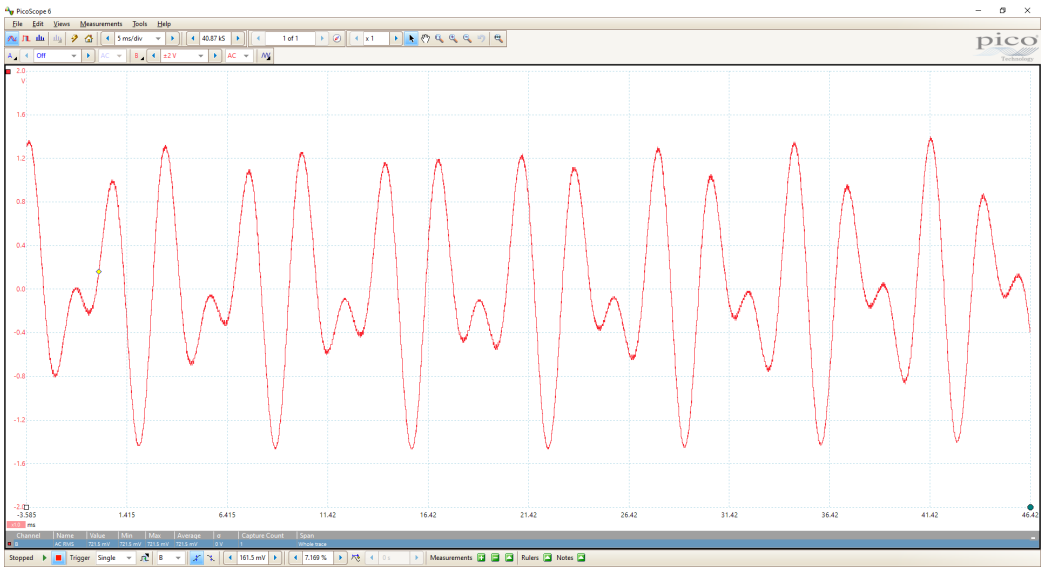


Worksheet 8 - Reverberation

Blue = initial signal
Red = echoed signal



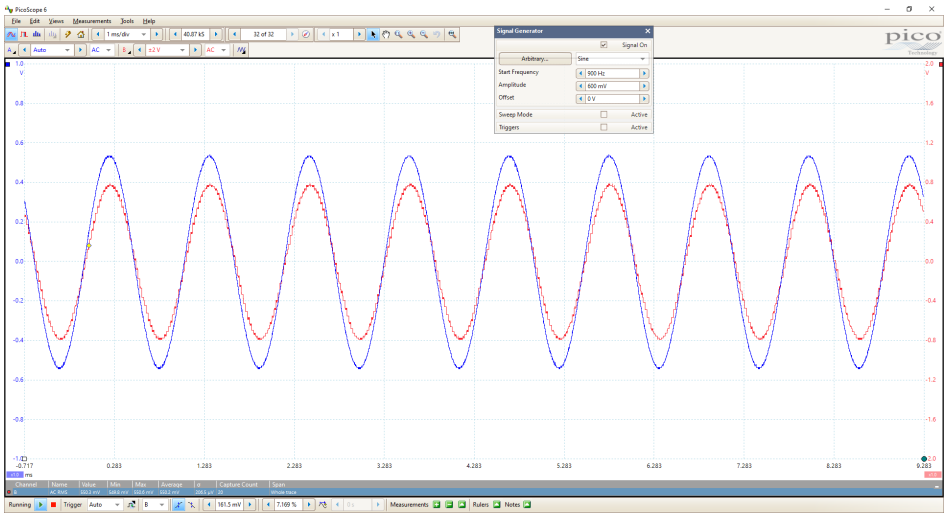
Worksheet 9 - Mixing signals



Results

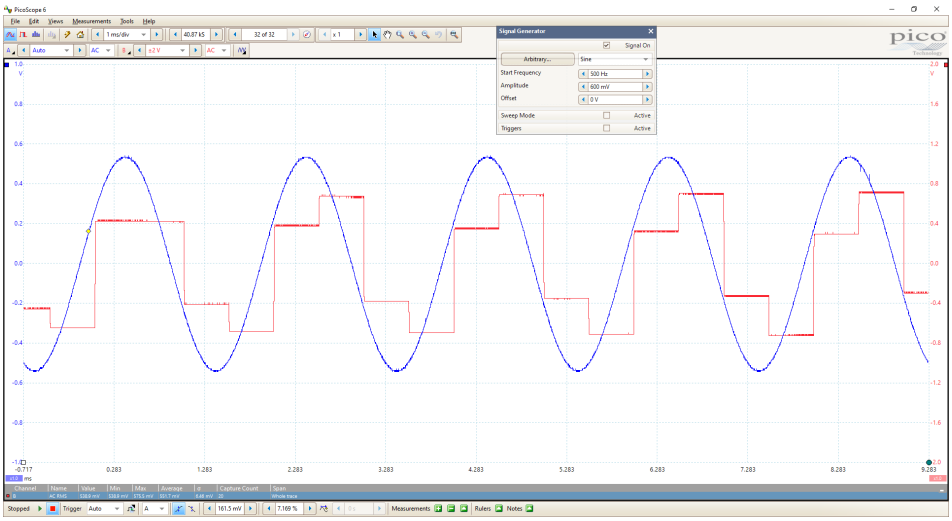
Worksheet 10 - equalisation

Blue = input signal
Red = output signal

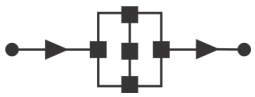


Worksheet 11 - sampling

Blue = input signal
Red = output signal



Version control



Music with microcontrollers

30 11 23 first release