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# PIC SPECTRUM ANALYSER

JOHN BECKER



*Graphically displays frequency content of any waveform, using sophisticated, but automatic, mathematical analysis routines.*

A SPECTRUM analyser is a sophisticated workshop tool that allows you to analyse a waveform of any shape and establish which frequencies it contains and at which relative amplitudes.

The design presented here analyses input signals up to about 50kHz and displays frequency content to around 400kHz. A signal interface board is controlled by a PIC microcontroller and outputs digitised data to a PC-compatible computer which analyses the data and displays it graphically on its VDU.

Such displays can assist in improving many types of electronic hardware design.

## HARMONICS

By its nature and definition, a "pure" sine wave is comprised only of a single frequency. Other waveforms, although seemingly simple in appearance, are actually comprised of a whole variety of frequencies at different amplitudes. A frequency counter may show, for example, that a sine wave and a square wave are both occurring at the same given number of cycles per second, but it is the *fundamental* frequency of the waveforms to which the counter is responding. The counter ignores

the numerous minor frequencies implicit in a square wave.

In non-sinusoidal waveforms, frequencies that occur in addition to the fundamental are known as *harmonics*. A pure sine wave has no harmonic frequencies. In other simple waveforms, the harmonics and their frequency distribution are directly related to the shape of the waveform. They are always at a higher frequency than the fundamental.

Harmonics are most abundant in square waves, non-existent in *pure* sine waves (which are not sine waves if they contain harmonics!) and progressively less abundant as a square wave becomes increasingly filtered to become sinusoidal. Waveforms such as triangles, ramps and pulses all contain varying quantities of harmonics.

Complex waveforms, such as occur in speech and orchestral music for example, not only have specific harmonic contents at a given moment in time, but also vary their content across time. This can result in harmonics being created at frequencies *lower* than the various fundamentals.

## SPECTRAL DISPLAY

The aim of a spectrum analyser is to

analyse the "spectrum" of the harmonic frequencies occurring in waveforms, simple or complex, and display the contents in various graphical forms. With the abundance of computers, the most convenient form of display is via their screens.

Armed with such a display, and possibly a screen dump of it to a printer, the frequency content of any signal can be assessed. This allows, for instance, a designer to modify the design of an audio circuit, or perhaps the settings of a signal generator, so that the desired response can be tailored.

## ANALYSIS TECHNIQUES

So far as is known, there are three ways in which frequency (spectrum) analysis can be performed. One is to use a bank of numerous filters, each responding to a different frequency. Another is to repeatedly feed a recorded signal through a variable filter whose narrow passband is swept across the full spectral range. Such techniques can achieve incredibly accurate results. They are, though, complex and expensive to build.

The third option, as used here, is to analyse waveforms mathematically once they have been sampled. There is a drawback, however, to analysing waveforms in this way compared to using filtering techniques.

Sampled waveforms consist of discrete data values taken at separate instants in time. As such, the sampling process itself introduces its own harmonics. These can be ignored when the input signal consists of frequencies well below the sampling frequency.

As the two become closer, though, the accuracy of analysis becomes less reliable. Although harmonic data will be displayed, it will become increasingly influenced by the sampling rate.

While the unit described here will accept input signals in excess of 50kHz, the analysis should be regarded as being more accurate for signals within the audio range.

## FOURIER ANALYSIS

The theory of frequency analysis through mathematical techniques goes back to the early 1800's, although it took modern computing to come along to really make it a practical proposition.

French mathematician Jean-Baptiste Joseph Fourier (1768-1830) was the man

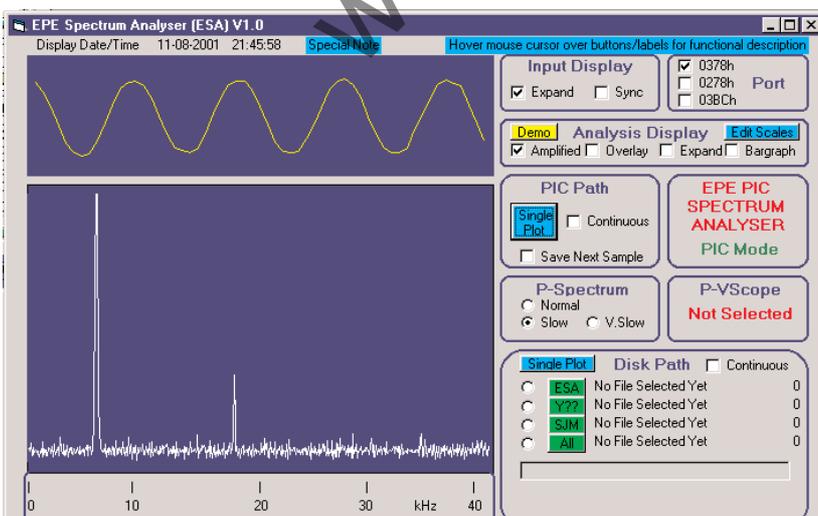


Fig. 1. Spectral analysis of a poorly shaped sine wave.

who originated the idea, although variants of his technique have since evolved.

Fourier realised that a waveform could be analysed or broken down into component sinusoidal (sine or cosine) waves. Similarly, any waveform could be generated by combining selected quantities and amplitudes of these components. His technique is widely known as Fast Fourier Transform, FFT.

### EXAMPLE WAVEFORMS

In Fig.2 is shown a “screen dump” of the spectral graph for a sine wave generated by a computer and analysed by the Spectrum Analyser software. It shows a large single peak at the left. Its position horizontally shows that it is placed fairly low in the audio spectrum. In this instance, the display has not been related to any scale.

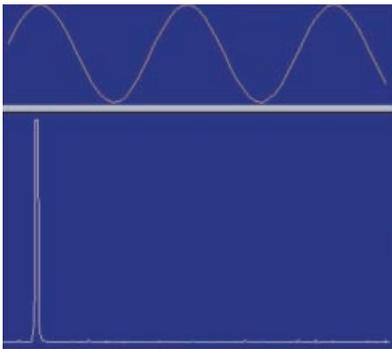


Fig.2. Analysis display for a pure sine wave.

The screen dump in Fig.1, though, shows the “real-time” analysis of an impure sine wave generated by a low-quality signal generator that has seen better days! Not only is the signal not truly sinusoidal, but it also has noise superimposed on it.

The signal frequency is nominally about 6kHz (main peak), but a very distinct secondary peak is seen at about 18kHz, reflecting the waveform’s non-purity. There are also minor peaks across the range and most of these are associated with the signal’s noise content, although at least one, at about 35kHz, could well be caused by the waveform. Had the signal been truly sinusoidal, only the 10th hand peak would have been shown, as in Fig.2.

In Fig.3 is shown the analysis graph (on a broader display scale) for a square wave whose fundamental period is similar to

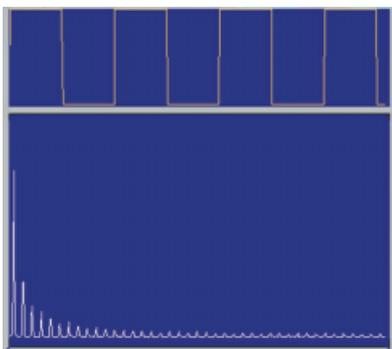


Fig.3. Harmonics contained in an analysed square wave.

that for the near-sinewave in Fig.1, but look at the harmonics now shown!

The fundamental is shown to the far left, while the harmonics extend across the full range, steadily decreasing in amplitude. This illustrates the nature of harmonics, those closest to the fundamental frequency have the greatest amplitude. Those furthest away have the least.

As commented earlier, some of the harmonics will have been created by the sampling process itself, but most are due to the nature of square waves. Note also that the upper window shows how the sampling process has resulted in the edges of the square wave deviating slightly from the vertical.

The graph in Fig.4 shows a software-amplified display of the same analysis peaks. Those to the far left have been clipped to keep them within the bounds of the screen window.

Each harmonic has a direct relationship to the frequency of the fundamental and to other harmonics to either side of it. The reasoning is mathematical, though, and will not be discussed.

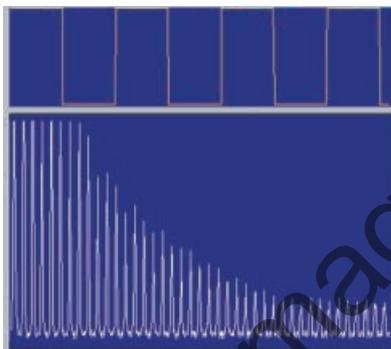


Fig.4. Amplified display of square wave harmonics.

### HARDWARE INTERFACES

The software described later has been designed principally for use with the PIC Spectrum Analyser hardware presented here. However, by intention, it can also be interfaced to the PIC Dual-Chan Virtual

Scope (P-VScope) – published in Oct ’00 – without any modification to that design, although with a much lower frequency range.

As usual with many of the author’s designs that interface external frequencies to a computer, the principle behind the PIC Spectrum Analyser hardware is that sampling is done at the fastest possible rate. The hardware temporarily stores it in a buffer memory, and signals to the PC when the buffer is full, in this case, after 32 kilobytes have been sampled.

On receipt of a signal from the interface, the PC extracts the data byte by byte, and stores it in its own memory. When the full block has been received, the PC signals to the interface to start taking the next batch of samples. The PC then performs its analysis and displays the results on screen. The overall maximum rate of processing depends on the speed of the PC.

### ANALOGUE BUFFER

The circuit diagram in Fig.5 is for the simple analogue signal pre-conditioning “front-end” that is used prior to the sampling circuit. It comprises a single op.amp buffer, IC1a, which has two levels of gain, set by switch S1 between  $\times 1$  and  $\times 10$ . Switch S2 allows the signal to be a.c. or d.c. coupled, although in most instances only a.c. coupling will find significant use. The post-processed signal is output to the ADC’s input (IC4, pin 8 in Fig.6) as a d.c. level.

Using a TL082 op.amp, as shown, the maximum output signal level obtainable is 3V peak-to-peak, after which clipping occurs. Other op.amps having rail-to-rail output swings could be used instead. The input to ADC pin 8 must always lie in the range 0V to +5V. DO NOT attempt to feed external signals that are outside this range directly into the ADC input. Note that the “scope” display in the upper area of the screen is also limited to about 3V pk-pk maximum.

In a quiescent (no signal) a.c. state, the d.c. output level is approximately 2.5V, as set by the potential divider formed by resistors R5 and R6, and smoothed by capacitor C6.

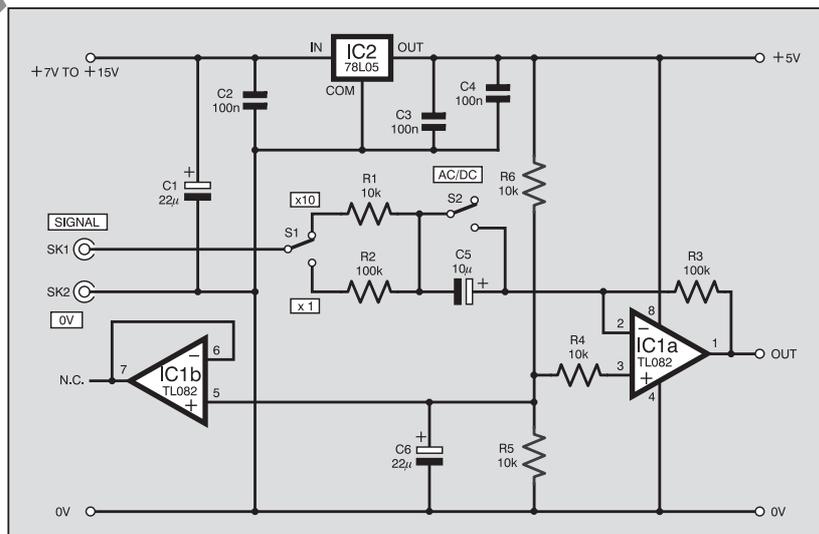


Fig.5. Circuit diagram for analogue signal pre-conditioning “front-end”.

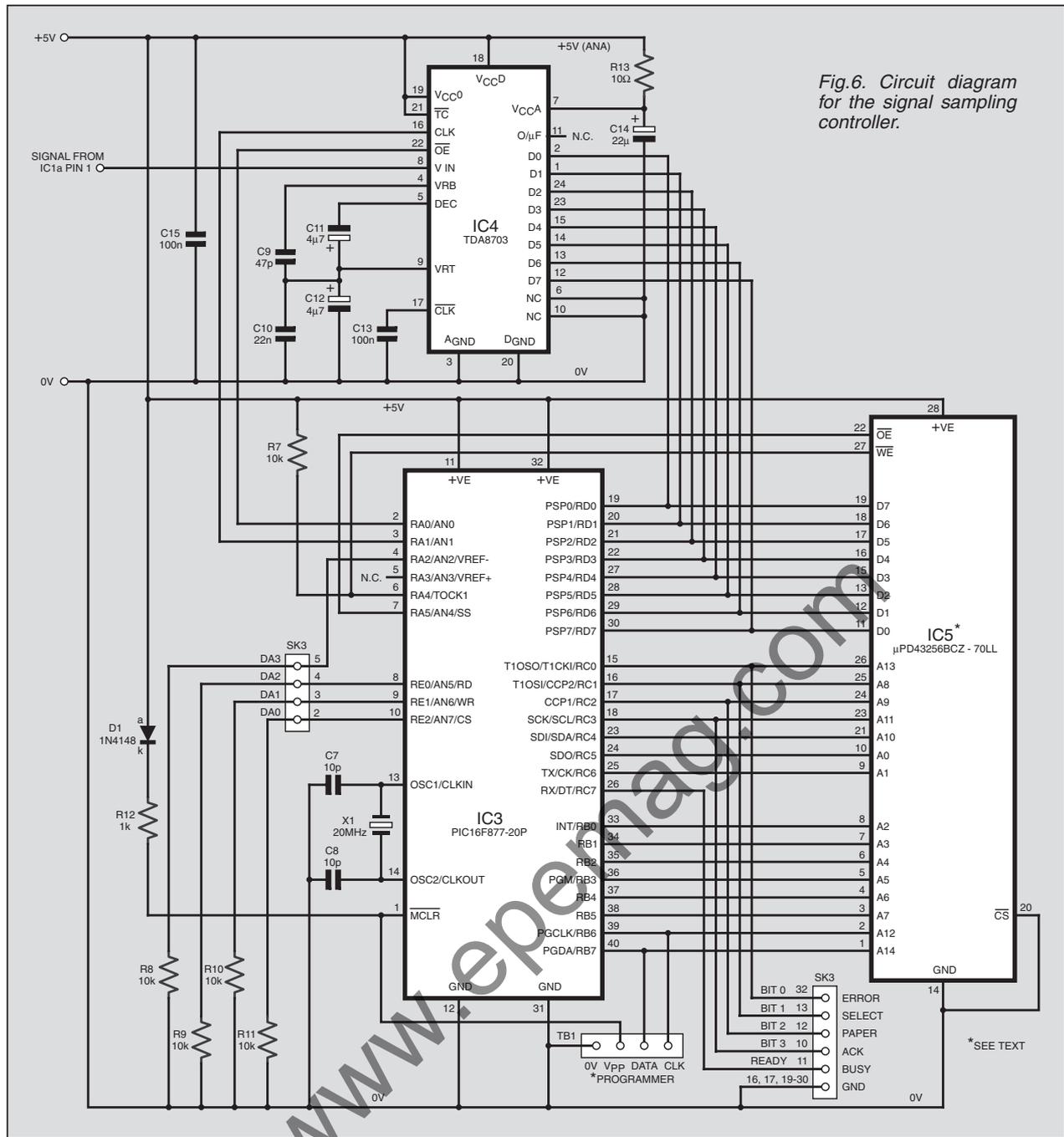


Fig.6. Circuit diagram for the signal sampling controller.

**SAMPLING CIRCUIT**

The circuit diagram for the signal sampling controller section is shown in Fig.6. The PIC16F877-20 microcontroller, notated as IC3 and running at 20MHz, is in charge of the process. Its first task is to control the analogue-to-digital converter (ADC) IC4. The PIC's own internal ADC is not fast enough for use with this design. The external ADC receives analogue audio signals at its Vin pin. The PIC repeatedly sends conversion pulses from its RA1 pin to IC4's CLK pin. The effective sampling rate is approximately 100kHz.

Shortly after each CLK pulse, allowing a suitable conversion time to suit the 40MHz ADC, the PIC sets the ADC's output enable pin (OE) low. In response, the ADC presents the converted data in 8-bit binary

format to its D0-D7 outputs. These outputs connect to the D0-D7 inputs of the 32 kilobyte SRAM (static random access memory), IC5.

The memory's read/write input/output function pins WR and OE are controlled by PIC pins RA4 and RA5. RA4 is biased via resistor R7 to the +5V line as it has an open-collector output.

To latch data into the memory, WR is taken low while OE remains high. The PIC then increments an internal 2-byte counter and outputs its value via Port B and Port C to the memory's address pins A0-A14. The memory is now ready to accept the next data byte at this updated address.

When the counter has reached its maximum and Port C pin RC7 goes high, the system now goes into readback mode in which the ADC is inhibited and data is

output from the memory back to the PIC and then to the PC, via parallel printer port connector SK3.

Via its BUSY line connection, the PC responds to RC7 and starts issuing data retrieval commands, via its DA0 to DA3 data lines, to the PIC. In response, the PIC steps the memory through each of its addresses, retrieving bytes as it does so.

Each byte is output as two nibbles (four bits) to the PC via lines RC0-RC3 and the PC's "handshake" lines Error, Select, Paper and Ack (full credit to Robert Penfold for introducing us all some years ago to using the "handshake" lines).

On receipt of each data byte, the PC stores it and signals to the PIC to send the next byte. This continues until all bytes have been transferred. The process then starts again.

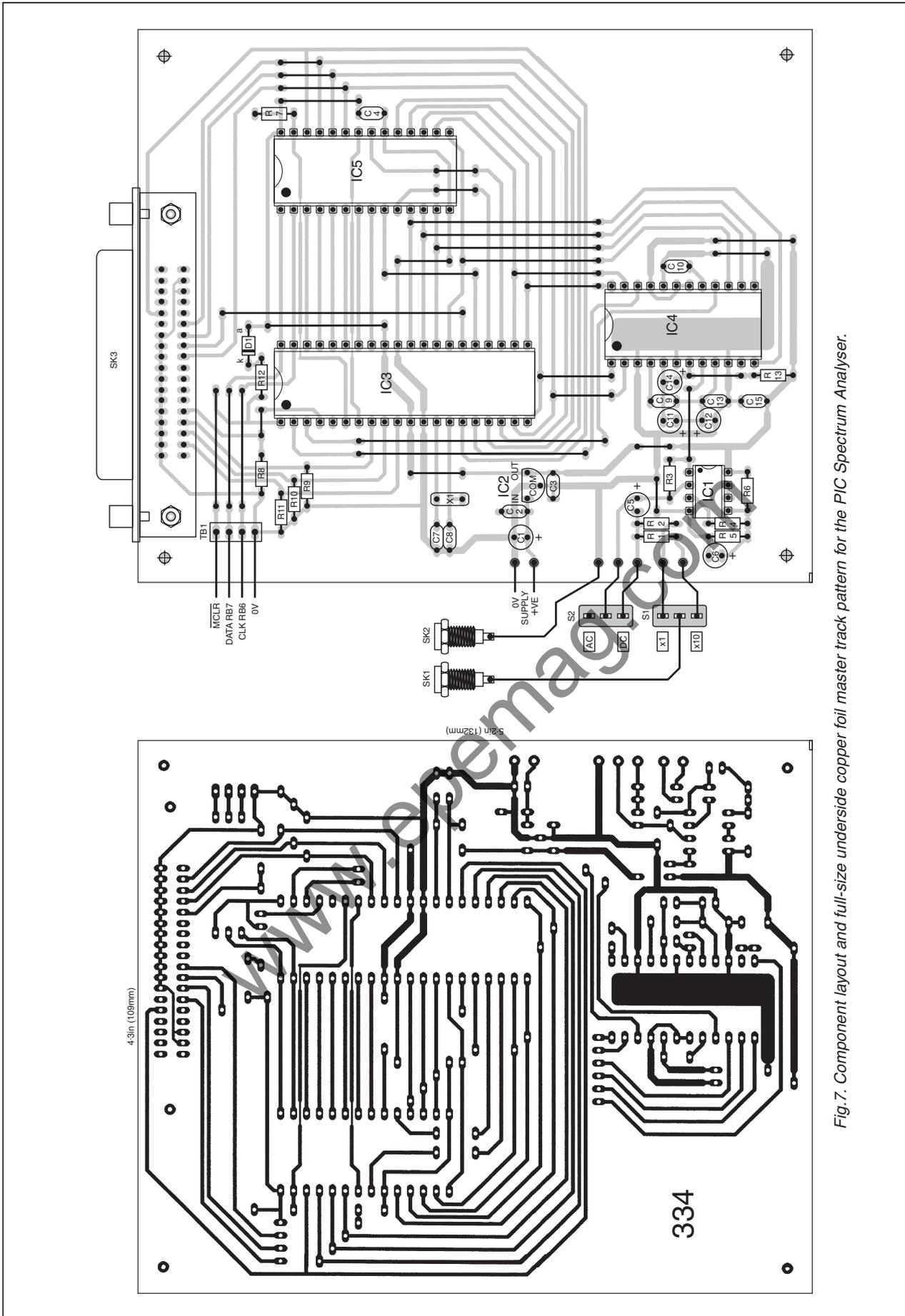


Fig.7. Component layout and full-size underside copper foil master track pattern for the PIC Spectrum Analyser.

## POWER SUPPLY

It is intended that the unit should be powered from a d.c. source between about 7V and 15V, preferably from a bench power supply, although a 9V battery could be used for a short period. IC2 (Fig.5) regulates the d.c. source down to +5V, as suits the digital circuitry (**do not exceed 5V**).

Current consumption of the complete unit is quite heavy, at around 73mA.

## CONSTRUCTION

Component and track layout details for the printed circuit board (p.c.b.) are shown in Fig.7. This board is available from the *EPE PCB Service*, code 334.

Insert and solder the inter-track links first, using 24s.w.g. enamelled copper wire. It does not need to be insulated if you ensure that the links are moderately straight and not in danger of touching each other.

Use sockets for the d.i.l. (dual-in-line) i.c.s., but do not insert these i.c.s until the correctness of the power supply has been fully checked. Regulator IC2 must be inserted, though. Insert and solder the other components in order of size.

Check the soundness of your assembly, including the adequacy of the soldering and the correct polarity of components as appropriate.

Connect the board to a suitable d.c. power supply and ascertain that +5V exists at strategic points around the board, referring to the circuit diagrams as necessary.

When satisfied, power down and insert the remaining i.c.s. If the PIC has not yet been programmed, you can do so now via *PIC Toolkits MK2 or Mk3 (TK3)* (July '98 and Oct/Nov '01 respectively) and pin-header TB1. This has its pins in the author's standard order. (Alternatively, you can buy a preprogrammed PIC – see *Shop Talk*.) Referring back to Fig.6, it will be seen that resistor R12 and diode D1 permit the correct use of the PIC's MCLR pin 4, both during and after programming.

A case is not used with the prototype and the choice of a suitable one if required is left to the constructor. The author connected the switches using short lengths of 18 s.w.g. enamelled copper wire.

## SOFTWARE SOURCE

Software for this design is available for free download from the *EPE* ftp site, or on

3.5 inch disk (for which a nominal handling charge applies) from the *EPE* Editorial office. See the *EPE PCB Service* page for more details.

The PIC program is supplied in three file formats, the source code (ASM written in TASM), HEX code (MPASM) and OBJ code (TASM).

Software for the PC has been written in Visual Basic 6 (VB6) and is supplied as an "executable" (EXE) file that ideally requires VB6 to be already installed. However, if you do not have VB6, you need to also copy in the contents of the "VBRuntime" folder as well.

Create a folder called SPECTRUM (or any name of your choice) and unzip all files into it, (including the above VB files if necessary) using a facility such as WINZIP (available for free download from [www.winzip.com](http://www.winzip.com)).

Ensure that you use a recent edition of WINZIP otherwise filenames might become corrupted, causing a system crash. Older versions of some unzip facilities truncate file names to eight characters plus extension. Some file names for this design are much longer.

Readers familiar with VB6 will recognise that various VB6 source code files are included with the software. Other files are included that are for demonstration purposes from within the program.

## PC INTERFACING

Connect the PC's parallel printer port via a standard Centronics printer cable to the p.c.b. and switch on power.

From within the SPECTRUM folder, double-click on the SPECTRUM icon to launch the program. (The full name of the icon, which might not be shown by your PC, is SPECTRUM.EXE.) You should be greeted by a screen similar to that shown earlier in Fig.1, but without any waveforms, of course!

This is the "front page" through which the primary data analysis is done. There are other options discussed in a moment. The program has been written for use with an 800 x 600 format screen. There will be a slight cut-off at the righthand side of the screen for users only having a 640 x 480 format, but all the essential click-options are visible.

# COMPONENTS

### Resistors

R1, R4 to R8, R10, R11	10k (8 off)
R2, R3, R9	100k (3 off)
R12	1k
R13	100Ω

See  
**SHOP**  
**TALK**  
page

### Capacitors

C1, C6, C14	22μ radial elect. 16V (3 off)
C2 to C4, C13	100n ceramic, 5mm pitch (4 off)
C5	10μ radial elect. 16V
C7, C8	10p ceramic, 5mm pitch (2 off)
C9	47p ceramic, 5mm pitch
C10	22n ceramic, 5mm pitch
C11, C12	4μ7 radial elect. 16V (2 off)

### Semiconductors

D1	1N4148 signal diode
IC1	TL082 dual FET op.amp (see text)
IC2	78L05 +5V 100mA voltage regulator
IC3	PIC16F877-20P microcontroller, preprogrammed (see text)
IC4	TDA8703 analogue-to-digital converter
IC5	μPD43256BCZ-70LL 32KB SRAM

### Miscellaneous

S1, S2	min. s.p.d.t. toggle switch (2 off)
SK1, SK2	input signal connector(s) to suit application. e.g. 2 x 2mm sockets)
SK3	Centronics 36-way female connector, right-angled p.c.b. mounting
X1	20MHz crystal

Printed circuit board, available from the *EPE PCB Service*, code 334; case to suit (see text); p.c.b. supports (4 off); 8-pin d.i.l. socket; 28-pin d.i.l. socket; 22-pin d.i.l. socket; 40-pin d.i.l. socket; 4-pin 1mm pinheader (see text); 1mm double-sided terminal pins; linking wire (see text); solder, etc.

Approx. Cost  
Guidance Only

**£39**  
excl. case

## DIRECTORY ACCESS

Some prerecorded and simulation waveforms have been included with the software, and it is worthwhile familiarising yourself with what spectrum analysis displays look like in action before you run the hardware.

The files available can be listed by clicking on the green ALL button at the bottom righthand side of the screen (see Fig.8). This calls up the directory (folder) sub-window which displays all files held in the Spectrum folder. Click the button now to reveal the display (see Fig.9). The files shown in Fig.9 are the author's and not included with the software.



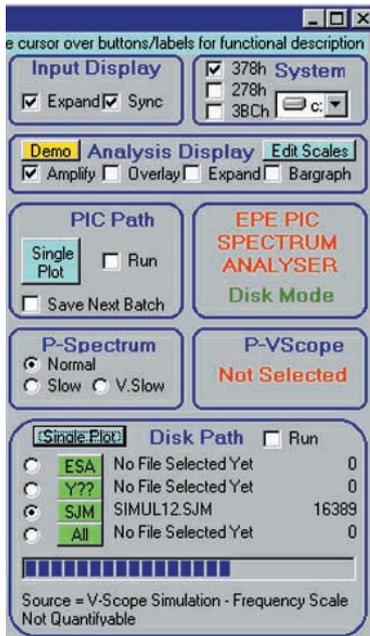


Fig.8. Control panels of the Spectrum Analyser main PC screen.

This directory facility is a cut down version of that used in the author's *PIC Toolkit TK3* software (Nov '01) and has many useful facilities included. It is too lengthy to discuss here, but notes about it can be viewed by clicking on its blue NOTES button. In a nutshell, though, double-clicking on any file name loads it into the Spectrum's allocated memory area.

Although all files having any extension are accessible by the ALL route, in practice you will normally only require files having the following extensions:

- ESA – waveform data recorded through the PIC Spectrum Analyser and its own software.
- Y?? – waveform data recorded by the author's previously mentioned *P-VScope*, where ?? represents the year number.

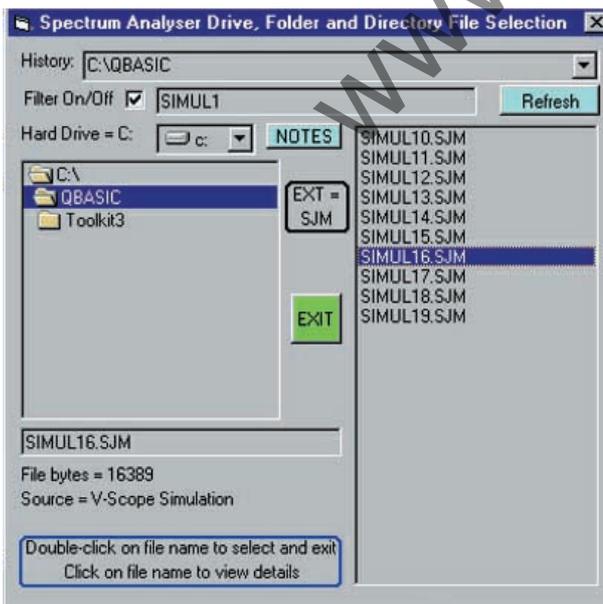


Fig.9. Folder and directory selection sub-screen.

- SJM – simulation files created by his original *EPE Virtual Scope* (Jan/Feb '98)

The other green directory buttons have these extensions labelled on them (see Fig.8). This allows you to be selective in which of the three main file groups you wish to search for a file.

Folder paths may be accessed in the usual Windows fashion by means of the lefthand sub-window of Fig.9.

Double-click on one of the file names having an SJM extension. This loads the file and returns you to the main screen.

Having selected and input a file, its name is shown alongside the button through which you accessed it. Until a file is loaded, other buttons will show No File Selected alongside.

On an 800 × 600 screen the file sizes will also be seen to the right. This is for information only and has no practical purpose.

## SIMULATION EXAMPLE

To the left of the green buttons are four small circular "radio" buttons. On clicking them a black dot appears at their centre. This causes the named file to be run through the analysis routine. If no file has been selected yet, you will be reminded by a sub-screen message.

Processing of a sectional block of file data commences immediately the radio button is clicked. The data is interpreted as a waveform in the screen's upper "scope" window. It will be seen to be "refreshed" at regular intervals. At each refresh the next block of file data is processed, until the file end has been reached, whereupon it recommences from the start.

Each data block's processing results are displayed as spectral analysis peaks in the lower "scope" window. With waveforms having SJM and Y?? extensions, the analysis is not related to any frequency scales, because the files do not hold such information that the software can use.

Files having an ESA extension, however, which are recorded by the PIC Spectrum Analyser *do* have associated frequency scale markings. These are shown below the analysis window (but hidden with other extensions), see Fig.1.

The Single Plot and Run options in the Disk Path zone allow you to single-step through waveform blocks, or run them continuously. A blue bargraph displays how far through the file data you have progressed.

## LIVE ANALYSIS

When you have viewed the analysis displays for several different files, return your attention back to your completed board assembly.

Connect a signal generator into its input and set the signal amplitude output for somewhere between about 1V and 3V peak-to-peak, with the op.amp's gain switch S1 set to ×1 and the coupling switch S2 to a.c.

Above the Disk Path zone are two other zones, marked P-Spectrum and P-VScope respectively. The latter should be empty of control options, with the message Not Selected shown, but the P-Spectrum zone should have three radio buttons visible (the default option when the program is first run).

The "Normal" button should be seen to be active, having a dot at its centre. The three buttons control the rate at which the hardware samples its data (Normal, Slow, V.Slow). Slow is ten times slower than Normal, and V.Slow is ten times slower than Slow. Slowing down the sampling rates allows lower-frequency signals to be sampled to give greater detail.

## PRELIMINARY HARDWARE CHECK

If you click between the three buttons now, the software will do a preliminary check that your cable is plugged in and the power switched on. If either situation is untrue an Error message will displayed telling you so.

Which brings us to setting the correct Port register used by your PC to access its printer port. There are three options likely, addresses 378h (hex), 278h and 38Ch. It is probable that your PC will be set for 378h, but not necessarily so.

If you see the said Error message, first double check that the power is on and the cable connected. Click the OK button and try again.

If the message appears again, and assuming that your assembly is satisfactory, try a different Port address. In the System zone at the top right of the screen, the three register addresses have dedicated option buttons. Button 378h will currently have a tick mark. Click on 278h to try that register. The previous message will reappear if it is not correct, in which case try 38Ch.

If still no joy, you are likely to have made an error in your board construction. Recheck it all and try everything again.

Assuming your board is OK and you have found the correct register (signified by the message not being shown), leave it selected. The information is stored to disk and will be recalled next time you load the program.

## HARDWARE RUNNING

Refer now to the PIC Path zone above the P-Spectrum zone. This allows you to select live analysis as a continuous process, or to single-step between live plots when you wish. Click on Continuous.

The system should now input waveform data from the board and analyse its content in the same way it did for your simulation tests.

Clicking Single Plot will stop continuous running and do as the button says. To step between plots press any keyboard key, or click the button again.

To sample data and record it to disk for future recall, click the Save Next Sample tick-box. A 2K block of live data will be stored at the end of the next batch. It is

filed with a unique date and time related name which is decoded when highlighting file names in the directory option and when a file has been selected. In the latter case, the information is displayed at the bottom of the Disk Path zone.

### INPUT WAVEFORM DISPLAY

The Input Display zone allows you to select how the input waveform is displayed in the upper "scope" zone. This is purely for information and has no bearing on the analysis. You have currently been viewing it in its default style.

Clicking on Expand widens the screen width distance between plotting points, drawing a line between them. This enables a better view to be seen when input waveform cycles are closely spaced. It does not affect the actual sample rate – it is purely cosmetic. The scale values do not change so you must mentally divide them by ten in this mode. Clicking again on Expand returns you to normal input display mode.

The Sync button cause the start of the waveform at the left of the screen to occur at similar positions in its amplitude. The triggering point cannot be changed – it occurs on the upwards slope, at somewhat over the midway voltage level (as seen by the ADC). Clicking Sync again turns it off.

### ANALYSIS DISPLAY

There are several options available through the Analysis Display zone.

The Amplify button amplifies the height of the analysis waveforms so that lower amplitude peaks can be more readily viewed (compare Fig.3 with Fig.4).

The Expand button is similar in action to the Expand button for the Input Display. It allows you to view the low frequency left-hand side of the analysis graph in "close-up". It effectively expands the display by 10 times, with the high frequency end not shown (see Fig.10).

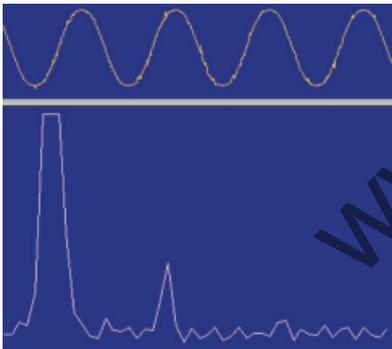


Fig.10. Analysis screen in Expand mode.

The Overlay button causes successive analysis data to be superimposed on the previous batches, allowing a complex display to be built up over time. This is useful when sampling signals whose content is constantly changing and you wish to know which frequency bands prevail most strongly (see Fig.11).

Clicking Bargraph displays the analysis peaks as individual vertical lines, allowing frequency differences to be more readily seen (see Fig.12).

All four option buttons work on an on/off alternating cycle.

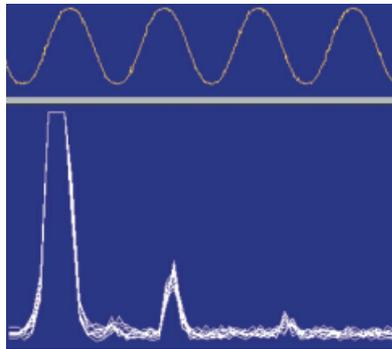


Fig.11. Analysis screen in Expand mode with overlay active.

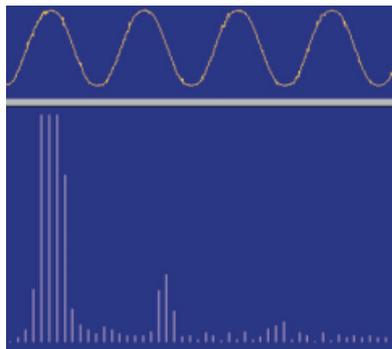


Fig.12. Analysis screen Expand and Bargraph modes active.

### EDIT SCALES

When in live sampling or ESA playback modes, frequency scales are shown below the analysis window. The actual values shown are those set for the prototype unit. Individual units may exhibit slightly different sample timings, due to normal variations in the exact frequency generated by the crystal. Consequently, the scales can be edited to suit.

Click on the Edit Scales button. Both scale markings will now be displayed with a white background rather than the usual grey. A yellow Save Scales button is also revealed (see Fig.13). Click the mouse cursor on the scale strip you wish to amend. The scale is now in "text" mode and information can be entered into it by any of the usual keyboard keys.



Fig.13. Typical scale editing display.

In the upper scale, graduation lines are shown. These may be pulled back by using the Delete key, or pushed forward by the space bar. This allows you to feed the unit with a signal (preferably a sinewave) of known frequency, from a signal generator, and the scale graduations can then be shifted if necessary to match the known frequency.

Similarly, click on the numeric scale and the values there can be shifted as required, and their values amended. Additional graduations and values can be entered if you want.

When satisfied, click on the Save Scales button in order to save the new data to disk. A confirmation message will then appear, "Scales saved OK". The revised scales will be recalled next time you run the program.

Note that there are five sets of scales available. The program automatically selects the correct scale for the hardware mode. Three are specifically for use when the PIC Spectrum hardware is used, with a pair for each sampling rate available.

If you use the P-VScope hardware, selecting it by clicking in the P-VScope zone, the other two pairs are used, again depending on the sampling rate chosen. All pairs can be independently amended and similarly saved to disk.

The P-VScope is a dual-channel design, and the Channel button included in its zone clicks between the channels. Should you wish to return to using the PIC Spectrum hardware, click on its zone, an action which then hides the P-VScope zone buttons again. Information on which hardware zone is currently being used is stored to disk for future recall.

### POP-DOWN NOTES

All screen buttons and most captions have messages "behind" them which are activated when the mouse cursor is hovered over them. These give brief details of the functions performed via the associated screen areas. Moving the cursor away from the message hides it again.

The message options cannot be switched off, nor does VB6 appear to allow them to become hidden after a given time, unlike some programs the author has used. If the messages get in the way, move the cursor well away from active zones (to outside the main screen area, for instance).

### DRIVE BUTTON

At the top right of the screen in the System zone is a Drive button. This allows you to tell the program which drive letter should be regarded as your hard drive. The options offered depend on the drives installed or partitioned on your machine. Do not select a drive into which you insert floppy disks or CD-ROMs.

The effectiveness of this option is not known since none of the author's machines have a partitioned drive. It seems to be a facility that could be useful, however. Reader feedback on this would be welcomed at EPE HQ.

### PROGRAM EXIT

Two options for exiting the program are available. The most obvious is via the standard Windows X button at top right. Not so obvious is the option to click on the zone words EPE PIC SPECTRUM ANALYSER, which has the same effect. Either path may be used.

### DEMOS

At the heart of the VB6 spectrum analysis software is a short mathematically-based routine. This is a variant of a routine given in a three-part article, written by the late Paul Cuthbertson, for EPE's sister publication the *Modern Electronics Manual* (appearing in quarterly Supplements 61 to 63). Part one was on the theory of spectral analysis. Parts two and three included various software examples

and an elementary hardware construction design.

Experimenting with the software, the author was so impressed by its apparent capabilities, it became the inspiration for this PIC controlled design.

The principle behind the analysis routine is too mathematical for the author to understand or describe. However, for the sake of those who might like to ponder how the analysis is achieved, the original MEM routine is supplied on disk with the other software for this PIC-based design.

Additionally, a demo program has been prepared and which can be accessed via the yellow Demo button in the Analysis Display zone. It needs waveform data to have already been loaded into the program before it can be run. This may be done via the Disk Path buttons, or directly through the hardware.

### DEMO PANELS

With waveform data loaded, click on Demo to display another sub-window. This contains four display panels (see Fig.14).

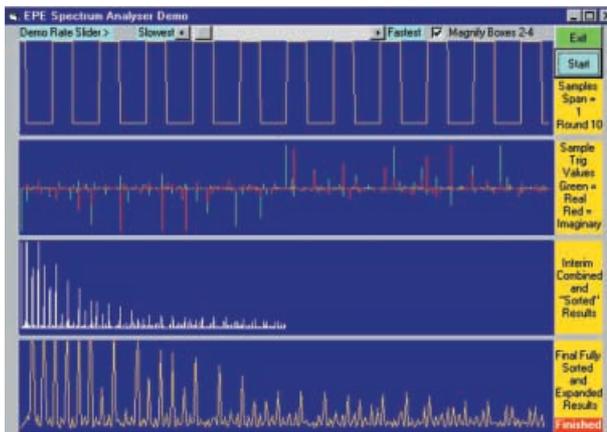


Fig.14. Analysis process demonstration screen example.

The top one shows the basic waveform. On clicking the blue Start button, the first stage of analysis begins. Pairs of waveform values are sampled at successive intervals along the length of the full sample batch of 1024. The screen displays each span-line superimposed on the basic waveform, illustrating the points between which the sample values are being taken.

On the first round, the span between points is half the total number of samples (512). An example taken at an early stage when sampling a sinewave is shown in Fig.15. The analysis relates the difference between the sample values to specific (pre-calculated) sine and cosine values. Each result is stored in sequence.

Sampling at this span interval commences at sample 1 and proceeds for 512 samples. Round 2 then commences, again from sample 1, but this time the span is half the previous (256) and two pairs of samples are taken, the second pair commencing 256 places after sample 1. The process

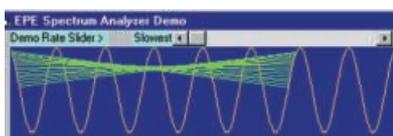


Fig.15. Example of the sample spans in the first stage of analysis.

proceeds through 10 rounds, each round the span being halved and the sample pairs doubled. Fig.16 shows an example during the third round.

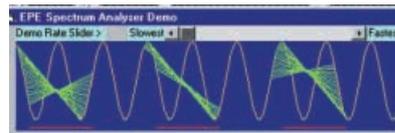


Fig.16. Example of the sample spans in the third analysis stage.

### SINE VALUES

The second panel shows the calculated sine/cosine values being stored in position as they occur. Fig.17 shows an example taken during the fourth round when sampling a square wave.

Paul Cuthbertson stated that some values are regarded as "Real" and others as "Imaginary", for reasons not understood. They are displayed in different colours. During analysis, the Real and Imaginary samples are combined in relation to their span positions, so reducing the number of calculated samples, while increasing the values of those retained.

The sample positions are directly related to equivalent frequency spectrum values, the higher the value, so the greater detected dominance of the equivalent frequency. Panel 2 (in normal mode) shows all sample position values as they occur.

There is a "magnify" mode in which



Fig.17. Example of sine/cosine values display during analysis of a square wave, round 4.

only the retained values are shown in each round, and the sample values are also increased according to which round is being processed, to make the value differences more apparent. An example taken in round 6 for the square wave is shown in Fig.18.

The third panel shows the "retained" analysis values, but "sorted" into their final frequency-related positions, which are determined according to a complex mathematical procedure. Fig.19 shows panel 3 at the same point in time as panel 2.

The mathematics are not understood by the author, but he analysed the relationship between the original and "sorted" positions and created a look-up table that is used to position the values in panel 3. The table is held in software file SpectrumTable.txt and may be examined via a text editor.

### WELL SORTED

The final panel shows the graph of the final sorted spectral analysis values (refer back to Fig.14).

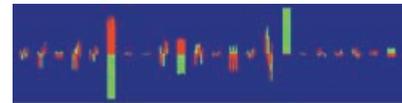


Fig.18. Example of panel 2 in round 6 for a square wave.

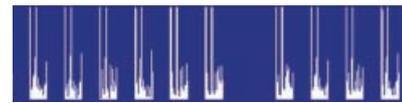


Fig.19. Panel 3 at the same point in time as Fig.18.

The demo window has various control buttons. The rate at which the demo progresses is controllable via a "slider" at the top. At its slowest rate, you can study each step of the process. The fastest rate illustrates the overall process more clearly as it progresses from round to round.

The values generated in panels 2 to 4 can be "magnified" via the top-right tick-box, allowing the differences between values to be more readily appreciated (as was done for Figs.14 to 20).

The demo may be restarted from the beginning at any time by clicking on the Start button. Apart from being informative, the demo can also produce some interesting patterns (three of which are shown in Fig.20).

Variants of the preceding paragraphs can be viewed by clicking the four yellow zones at the right of the demo screen.

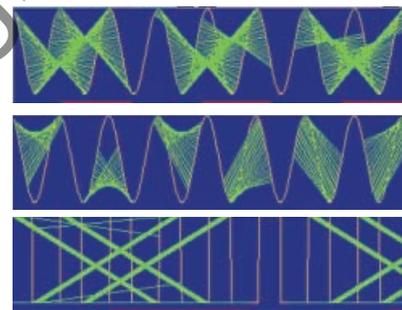


Fig.20. Three examples of "interesting" analysis patterns.

Buttons and text labels have underlying "messages" when the mouse is hovered over them. A return to the main screen can be made by clicking on Exit or the Windows X button.

Paul's original QBasic routines (written for his own hardware) can be read as a text file, SpectrumMEM.txt, which accompanies this program. It has its own explanatory comments.

### FURTHER READING

*Modern Electronics Manual*, Supplement 61. Paul Cuthbertson. Wimborne Publishing Ltd.

Charles Lepple describes FFT in simple terms and provides further links through his web site:

[www.foo.tho.org/charles/fft.html](http://www.foo.tho.org/charles/fft.html).

The Fastest Fourier Transform in the West is at [www.fft.org](http://www.fft.org). This site has its own FFT software and many links to other sites, plus a list of further reading, etc.

*Note that Figs. 10 to 20 have been "reversed-out" (black on grey) for clarity when printed.*