polyphonic synthesiser

. . . with a computer controlled keyboard

Faced with a wide selection of polyphonic keyboard kits, synthesiser enthusiasts have a hard time finding the right one, since most of them seem to have considerable disadvantages. After examining various systems thoroughly (the subject of long and heated discussions), Elektor's design staff decided on computer control. This article compares it to others and at the same time paves the way for the printed circuit boards and the constructional details which will be published in due course.

Why use a microprocessor?

Isn't the use of a microprocessor in this case a little like using a sledge hammer to crack a nut?, one may ask. After all, the FORMANT managed very well without. Like it or not, electronic music is becoming invaded by 'digitology'. Quite apart from anything else, the cost of the Z80, the microprocessor used in this project, is under five pounds, a good enough reason to give it serious thought!

In this particular case, a microcomputer was introduced because it was considered to be absolutely necessary. For one thing, a discrete solution would be vastly complicated and take up an awful lot of space. To find out why let us recap briefly on the last article in the monophonic series.

On a conventional polyphonic synthesiser keyboard every key requires a VCO along with the associated VCFs, VCAs and envelope generators. From now on we will refer to such units as 'channels'. A complete keyboard would therefore require a large number of channels and the synthesiser would end up filling an entire room. And the expense! The answer is much more straightforward, for a keyboard player, however brilliant, is seldom equipped with more than two hands. Thus, the maximum number of keys that can be depressed simultaneously never exceeds ten, one for each finger. By connecting the depressed keys to individual VCOs means that only ten synthesiser channels are needed to provide a sophisticated polyphonic instrument and that is where the microprocessor comes in. It is an ideal means of storing parameters, such as pitch, and allows the musician plenty of scope for developing his/her own ideas and programming these into the machine.

Synthesiser systems without microprocessor control have one main disadvantage: the only way in which they can find out which key was depressed is by means of keyboard multiplexing. In the case of a three-note chord, all the key contacts have to be scanned in turn. The control voltage of the first key that is acknowledged to be depressed is fed to the first VCO, that of the next key is fed to the second VCO, etc. As figure 1 shows, the control voltages at the VCOs shift while the instrument is being played. Supposing three keys are depressed and VCO1 receives 1 V, VCO2 is supplied with 2 V and VCO3 with 3 V. If the second key is released, VCO1 will continue to be fed with 1 V, whereas VCO2 is now supplied with the 3 V assigned to VCO3. As a result, the key corresponding to VCO3 is acknowledged as the second, rather than third, note in the chord.

Problems occur due to the gate trigger pulse, the sample and hold circuit and the decay time – releasing the second key is liable to cause a cacophonic surprise. The instrument simply cannot keep up with the changes without a brain, a microprocessor.

The main task of the microprocessor is to scan the synthesiser keyboard. After each scanning procedure, the details related to the state of the keyboard at that particular moment are stored in RAM. The computer compares the new data to that derived from the previous matrix configuration and then decides which keys were released and which ones have now been depressed. Whenever a key is released, the GATE signal at the control output becomes logic 0. However since the pitch code at the output remains unchanged, the note is able to decay at the right pitch.

If more than ten keys are depressed simultaneously, the computer must be able to pick out the ten initial notes. If a new key is depressed during the decay time of the ten notes, the processor determines which note should be interrupted and substituted for the new note. How this is done is extremely complicated, involving various time priority laws, which are based on the following principle:

During a 'run', a sequence of notes, a new channel is stored with voltage data for every new key that is depressed. This also applies to a string of notes that doesn't necessarily have to form a chord. This allows the notes to decay after their respective keys have been released. After the tenth note, all the memory locations are full of data. The computer acknowledges the note that was the first to be produced during the series and replaces the corresponding VCO data in its memory location by information referring to the new note, the 'eleventh' in the series.

There is one exception to this rule. If the same key is depressed and released repeatedly (as in staccato playing, for instance) the control voltage and the gate signal must always be fed to the same VCO. Otherwise, an additional VCO 'voice' having the same frequency would be heard. The Z80 software has taken this problem into account and avoids such interference.

Another reason for using a microprocessor is that it offers a tremendous amount of flexibility and allows the synthesiser to be constructed in stages, which is preferable nowadays with most hobbyists managing on a very tight budget. Unlike discrete circuits, where it's 'all or nothing', the facilities of a microcomputer can be extended simply

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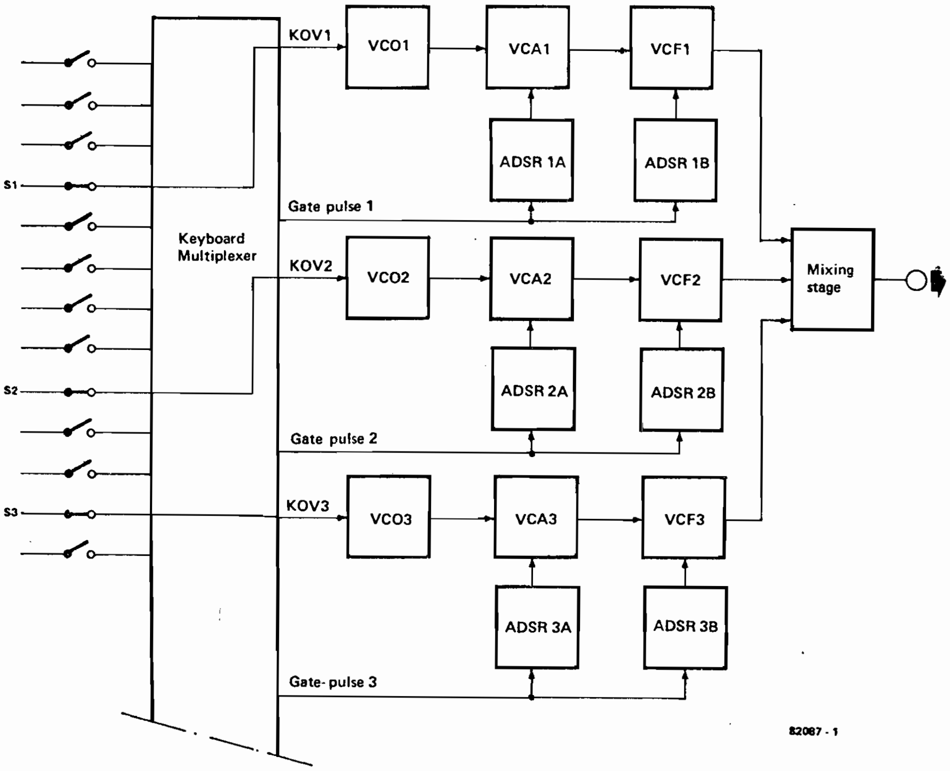

Figure 1. Any keys that are pressed are connected to a free synthesiser channel in order of pitch. When S2 (keyboard key) is released (see text) VCO2 assumes the control voltage produced by S3. This type of keyboard control is known as multiplexing.

by adding more memory cards to its bus system. It has the added advantage that EPROMs can be reprogrammed whenever required. Changing discrete circuits is almost impossible and costs a lot of time and money.

The brain behind the polyphonic keyboard

As mentioned earlier, the microprocessor used here is a Z80A. Its tasks fall into two main categories. Initially it 'collects' all the data from the key contacts and preset controls on the front panel. It then processes the data and assigns specific voltage values to the synthesiser modules under its control. Each of the connected synthesiser channels is provided with a 'pitch' and gate pulse. This is where the computer proves its flexibility, for readers who do not wish to spend too much all at once, can begin with two synthesiser channels and extend them gradually up to a total of ten. A select switch informs the processor how many channels are preset. The control voltage levels and the GATE pulse are in the form of a digital code, which are then 'translated' into the corresponding voltage values by the A/D-D/A interface board. The two range switches on the front panel of the synthesiser adjust the setting of each channel within a range of three octaves (12 semitones

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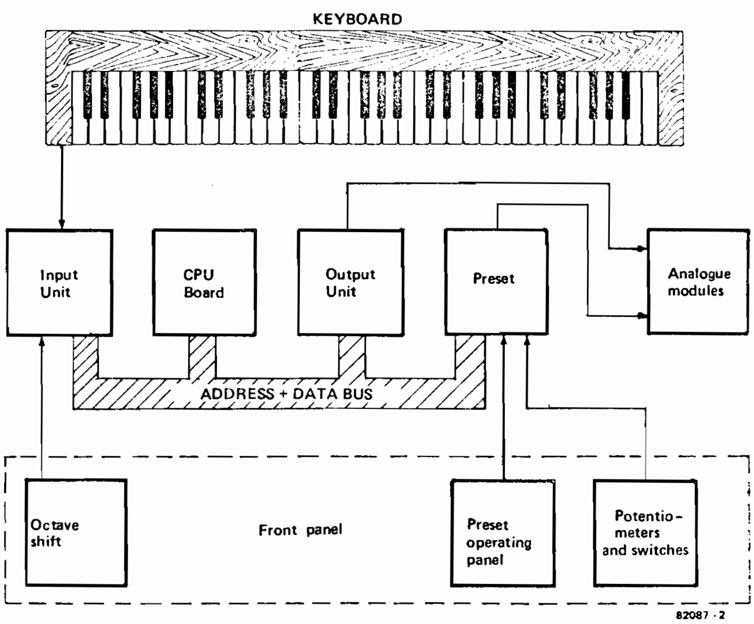

Figure 2. Block diagram of the keyboard/preset controller. This consists of a CPU card, an I/O device and the preset control logic.

and 2 octaves).
The second major task of the microprocessor involves controlling the presets. This enables a certain pitch or sound to be selected 'at the drop of a hat' with the aid of a single switch and saves fumbling around in the dark for the right lever, switch, etc. The operator has 64 preset (preprogrammed) sounds and an additional 64 memory locations to store personal tone compositions.

The hardware

The following section provides a detailed description of the hardware. This mainly consists of a debouncing circuit for the key contacts, a CPU board, an I/O circuit and various ICs which control the presets. The complete system is shown in the form of a block diagram in figure 2.

The preset unit

Figure 3 shows the keyboard and display matrix used to adjust the settings. The control unit includes the following facilities:

1. A keyboard containing keys 0 . . . 9, 'RAM' and 'CLR' (CLEAR) serves to select a certain sound. Each sound has its own program number and this is indicated on a two-digit 'SELECT' display.
2. A 'PANEL-PRESET' mode switch together with its LED which converts the pitch as stored in memory into the setting obtained by adjusting the controls on the front panel.
3. The 'STORE' key reads the sound adjusted by the pots on the front panel and stores it in EPROM. The storage procedure can only be performed provided the 'STORE ENABLE' switch at the back of the synthesiser is in the correct position when STORE is depressed. If so, the 'STORE ENABLED' LED on the front panel will light. This facility was included with a view to protecting musicians against involuntary acts of 'sabotage' by inquisitive friends and relatives who couldn't resist 'twiddling the knobs' . . . and prevents preset sounds from being accidentally overwritten. Discovering an erased synthesiser memory just before a concert is enough to cause a musician more sweat than the actual performance! Not that the audience is likely to notice any difference, where certain groups are concerned.
4. A significant feature of the preset circuit is its three channel sound stand-by circuit consisting of three ENTER keys and their corresponding displays and the PLAY 1 . . . 3 keys. Depressing the ENTER key causes the program number of a particular sound to be shown on the display. The settings shown on the three displays can be altered in a split second simply by pressing one of the three PLAY keys and operating the PANEL switch. The PLAY keys cannot be depressed simultaneously. After the 'PANEL' switch has been pressed (indicated by the LED on this switch), operating the 'STORE' key will transfer the current settings of the keyboard into the program number indicated by the 'SELECT' keyboard display. The selection can be any number between 1 and 64. It is also possible to select either the preprogrammed sound or a 'real time' sound, also numbered 1 to 64, by operating the RAM key on the keyboard. The latter is indicated by the presence of the decimal point on the display. The CLEAR key erases the SELECT display. Special software measures prevent an incorrect program number, such as 75 for instance, from being entered.

It should be mentioned that the total data for one particular sound may comprise 28 different analogue voltages ranging from 0 to +10 V and 32 data bits relating to the switch positions for the waveforms, etc. This may seem a bit of a luxury at this stage, but it might as well be included now, as it doesn't add much to the construction costs and will be needed later on anyway.

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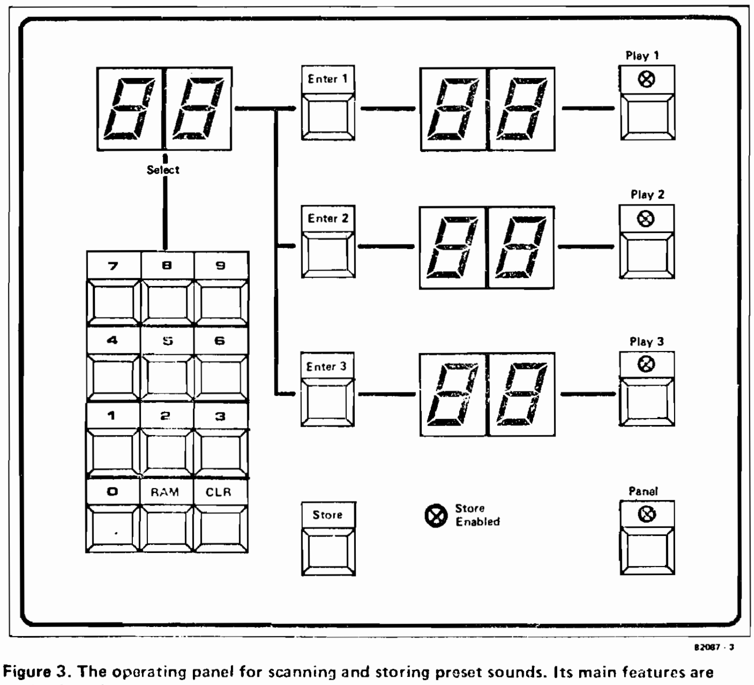

Figure 3. The operating panel for scanning and storing preset sounds. Its main features are the keyboard and displays. The program number shown in the top left-hand display may be temporarily stored in one of the right-hand displays to enable programs to be changed rapidly. This facility is ideal during live performances on stage.

One or two things to bear in mind

The next article in the series on the polyphonic synthesiser will provide printed circuit boards and constructional details. Readers should take various facts into account before 'diving in at the deep end'. The components can be fairly expensive and ideally, an understanding of analogue and digital circuits is desired. However, enthusiasm makes up for a lot and the printed circuit boards simplify the problems to a large extent.

The design staff decided against mounting a complete synthesiser on a single printed circuit board for the following reasons:

The printed circuit boards should be universal and suit the requirements of both monophonic and polyphonic synthesisers, leaving the choice up to the reader. The monophonic version must be able to accommodate a variety of combinations in the same manner as the FORMANT. The model based on the CURTIS ICs, as described in Elektor, is just one possibility. Anyone who has already built the FORMANT probably has personal ideas for a synthesiser using CURTIS ICs. At any rate, readers should decide beforehand whether they prefer a monophonic or a polyphonic synthesiser. It should be noted that the monophonic system published in Elektor cannot be elaborated into a polyphonic instrument in its present mechanical form. This does not apply to the CMOS switches, however, which are already available on the printed circuit board. These enable the preset facilities to be extended without the need for the complex microprocessor control unit designed for the polyphonic keyboard, but then, of course, no sounds can be stored. In any case, the preset unit can only be constructed if the keyboard controller is provided. K