Learn about electronic music:

Build an elementary "electronic organ"

Here is another simple novelty project which should appeal to beginners in the electronics field. Marketers of the kit on which it is based call it an "electronic organ", but this flatters it too highly. Nevertheless, it does serve to demonstrate the basic principles by which electronics can generate musical notes.

by WALTER NEVILLE

The basis of most electronic musical intruments is a circuit configuration known as an audio oscillator. As the term implies, such a circuit oscillates at an audio (audible) frequency and, if we feed the signal into an amplifier/speaker system we will hear a note similar to that produced by, say, a string vibrating at that same frequency.

In its most elementary form, such an oscillator is a relatively simple device. As a result, it is not hard to design a very simple electronic musical instrument.

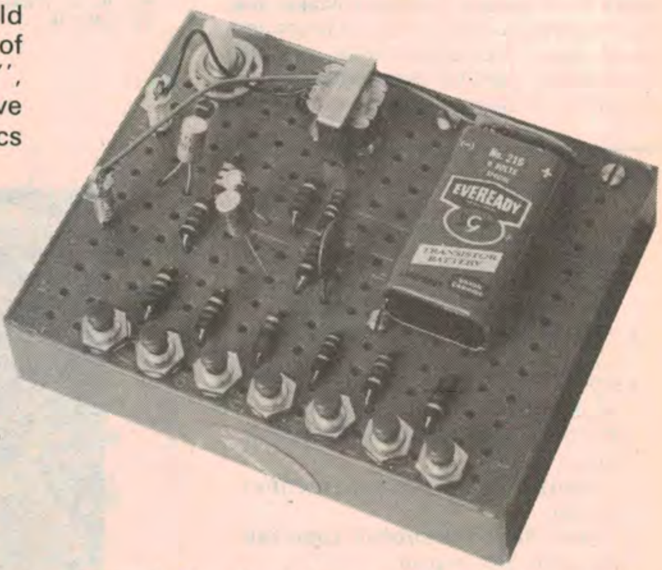
Of course there has to be a catch. Such a simple oscillator has many limitations, the most serious one being lack of stability, or a tendency to change its frequency of oscillation according to the temperature, the state of the battery driving it, the aging of components, and many other factors.

At the other end of the scale, more elaborate oscillators can be made extremely stable—far more stable than any conventional musical instrument can ever be. In fact, this is one of the major advantages of the best electronic musical instruments.

When we come to design a musical instrument based on the audio oscillator we can, once again, consider either a very simple concept—with a lot of limitations—or a very complex one but which will be very versatile.

Even the most elementary musical instrument should have at least eight notes. spanning one octave. If we want to add semitones (sharps and flats) then we need 12 notes in the octave. So what do we do; provide eight (or 12) separate oscillators, each adjusted to produce one note?

Or do we provide one oscillator with provision to change its frequency according to the note selected? The advantage of this latter arrangement is obvious; one oscillator does the work of eight (or 12). But there is a disadvantage too; with this simple arrangement we can play only one note at a time, whereas the previous arrangement allows us to play any combination of notes we desire.



The finished "organ". The pot, R12, is in the top left corner with the output transformer to the right of it. The seven push buttons are on the lower edge.

In spite of its limitations, the simple version—often referred to as a monophonic organ—is a popular one. They have been described in various magazines, including "Electronics Australia", and have even been marketed commercially. Provided one understands their limitations, they represent good value for the effort and money involved.

The version we are about to describe is based on a Science Fair Kit (No. 28-101), available from any of the Tandy stores for $5.95. It is probably the most painless way to acquire the necessary parts. At the same time, there is nothing special about any of the components; it should be possible to buy the equivalent from many electronics suppliers.

For those with some knowledge of circuits a glance at this one will immediately suggest a simple resistance-capacitance coupled amplifier, with Tr2 driving Tr1 and Tr1 driving a speaker. But what drives Tr2? From where does it get its signal? A closer look at the circuit shows that the input to the base of Tr2 comes from the collector of Tr1, via a network of switches, resistors, and a capacitor.

If we ignore the multiplicity of resistors for the moment, and the switches, we can assume that this network consists of a single resistor and capacitor. Regardless of the actual components used, any network which connects the output of an amplifier back to its own input is called a feedback network—for fairly obvious reasons.

Feedback may be designated as either "positive" or "negative" (according to the phase) but this is really too complex a subject to discuss here. Suffice it to say that the feedback in this case is positive. An important effect of positive feedback in any amplifier is to make it less stable and, if sufficient feedback is provided, the amplifier will go into oscillation.

And this, as we explained at the beginning, is just what we require of an audio oscillator. Equally important is the fact that the frequency at which this arrangement oscillates is determined by, among other things, the values of resistance and/or capacitance in the feedback network.

Another interesting aspect of this circuit is that, if it is redrawn according to popular convention, it suddenly looks very like another circuit configuration with which you may already be familiar; the so-called "multivibrator".

But whether you think of it in terms of

a multivibrator or simply as an amplifier with positive feedback, really doesn't matter; either definition can be justified in this case. The important thing is that the circuit functions as an audio oscillator.

By now you probably can appreciate the reason for the various resistors and switches in the feedback network. The switches, which take the place of the keys on a musical keyboard, will bring into circuit individual resistors which have been selected to produce a particular note. If all the resistors have just the right value each note will fit exactly into its correct place in the musical octave.

The circuit, as shown, has a number of limitations, even for a simple device. The first point that struck us is that it provides for only seven notes, rather than the eight normally regarded as a full octave.

Another is the use of a variable resistor (R12) for the S1 position, and which also remains in circuit in series with each of the other resistors, R1 to R6, as it is selected. The manual in the kit explains that this can be used to move the whole scale up or down. While this is true, we questioned whether it would retain the proper frequency ratio between notes at all settings.

We also queried the values of R1 to R6 on the basis that the ratios seem unlikely to provide the normal ratios between musical notes. And it is significant that the manual suggests that other value resistors may be substituted if desired.

We were also intrigued by the attempt in the manual to explain the relationship between resistor-capacitor combinations and frequency, in terms of the resistance-capacitance time constant. Even putting aside an obvious error in mathematics, the explanation can only be described as "quaint" and not to be taken too seriously.

All these suspicions were confirmed when we built the unit. In addition, it produces one of the most raucous sounds we have ever heard; so much so that the accuracy of the frequency, or "pitch" in the musical sense, becomes quite hard to determine. "Squawk" is the word that best describes the sound and one staff member suggested that the device should be called a "squawgon"!

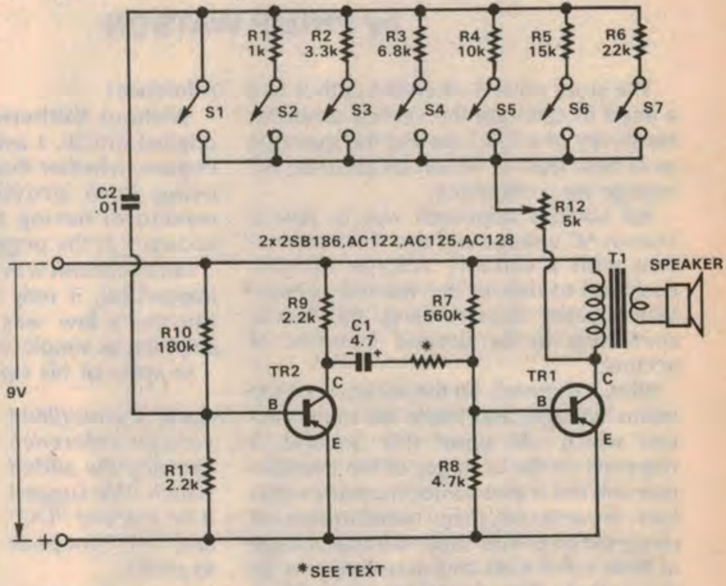
All of which adds up to a device with seven keys which produce seven squawks progressing up the scale by random increments. Its ability to produce even a simple melody would be doubtful.

Fortunately, these limitations are not insurmountable and would provide a challenge for the experimenter. The reason for the raucous note is simply that the system has far too much feedback for the gain of the amplifier section so that all stages—and also the speaker we suspect—are being grossly overloaded.

There are various ways in which the gain can be controlled but an easy one to try was to connect a resistor in series with one connection to the 4.75uF coupling capacitor, C1. We tried various values up to about 22k and these did make the note somewhat less raucous.

It also had a second beneficial effect; it reduced battery drain significantly. In its original form the standing current, before a button was pressed, was about 3.5mA and when a button was pressed rose to between 22.5 and 25mA, depending on the individual note. With a 10k resistor in series with C1 the standing current drops to 1mA and the operating current to a maximum of 15mA.

In our prototype a much closer approach to a correct note sequence could be obtained by using the following resistors in order: The 22k is retained for the lowest note, followed by 15k, 12k, 10k, 6.8k, 4.7k, and 3.9k. If the octave is to be completed, by fitting another button, the next value would be 2.7k.



The circuit, as shown, looks very like an amplifier, except that there is a positive feedback path from the output to the input. By varying the resistance in the feedback path the note can be varied.

But even with the 7-note arrangement it should be possible to pick out a "white notes only" melody, by playing the lowest note in place of its missing counterpart, one octave higher.

As with all these kits, assembly should present no problem. A perforated plastic box in which the components are packaged becomes a simple chassis. The rows of perforations are coded with letters and numbers which permits any individual hole to be nominated. The instructions make frequent use of this system establish the position of components.

In addition, there are drawings showing how to mount particular components, a layout diagram, and a circuit. Even a beginner should have no problems. As with the previous kits, we elected to make the various soldered connections without trimming the component pigtails. This preserves the components for use in other projects if, as is most likely, this project will be used only as an exercise and ultimately stripped down.

If you want to exercise some initiative, you could contrive something that looked like a keyboard, with a contact under each key. You could add sharps and flats by including extra resistors in the sequence where the semitones (or black notes) fit in the octave. If you could pick up a handful of oddment 20k potentiometers, the notes could be made tuneable. The whole pitch of the octave could be changed by selecting another value of capacitor instead of the .01uF in the feedback network. The loudness of the sound in the speaker could be reduced by wiring a low value resistor—less than 100 ohms—in series with one lead to the voice coil. None of these measures will result in a good "organ" but you'll be learning while you experiment!

As we mentioned earlier, the project need not involve the Science Fair kit. All the components should be readily available from electronics stores, even though a little more effort may be involved in collecting them.

The only components worthy of special mention are the transistors and the speaker transformer. The original transistors are 2SB186s; general purpose PNP types. There are a number of substitutes available and these are shown on the circuit.

The output transformer appears to be a standard push-pull type with primary impedance of about 500 ohms and a secondary of 8 ohms. There are several versions available locally.

There is nothing critical about the speaker and almost any 8 ohm unit should suit. The original was a nominal 50mm diameter type but any size would do.

And that is about all there is to it. We don't suggest that this device, or any tune that is played on it, will make musical history, but building it can be a lot of fun and you will have learned something. And when you tire of it, the bits will always come in handy for another project.