Experimenter's Corner

By Forrest M. Mims

PERCUSSION INSTRUMENT SYNTHESIZER

THANKS to John Simonton, and Don Lancaster, this magazine has featured articles on virtually every aspect of electronic music over the past several years.

Recently the electronic music bug bit me. Having tinkered with several of the basic circuits, I'm convinced that voicing circuits are by far the most challenging—and the most fun. Of course, they can be very difficult to implement, but the successful electronic synthesis of the unique "voice" or timbre of a particular musical instrument is quite rewarding.

Percussion instruments are among the simplest to simulate, so let's jump into electronic music by putting a percussion synthesizer together. Since percussion instruments include the bell, gong, cymbals, triangle, xylophone, tambourine, and drum, a successful percussion synthesizer has lots of uses!

The first step of a successful design is to study the waveforms produced by the instrument to be synthesized. If you're new to electronic music, be prepared for a surprise! "Ordinary" musical instruments produce some very extraordinary waveforms. To make matters even worse, the amplitude (signal strength) of the waveform during the first 100 milliseconds or so is usually irregular and often unique. For example, the cello has a gradual, slow amplitude rise time, but the tuba has a fast rise time in the form of a high-amplitude spike followed by the remainder of the sound "envelope." See Don Lancaster's article "Imitating Musical Instruments with Synthesized Sound" (POPULAR ELECTRONICS, August 1975, p. 37) for more information on the sound envelopes of these and other nonpercussion instruments.

Fortunately, percussion instruments produce a fairly orderly sound envelope. Figure 1 is a somewhat simplified version of the waveform

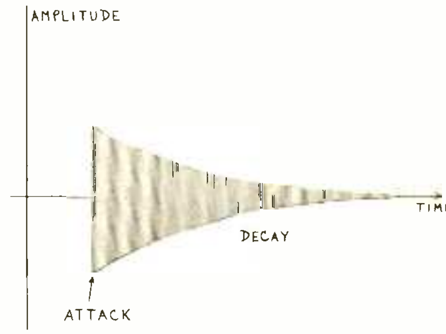

Fig. 1. In percussive waveform, rise is fast and decay slow.

produced by a typical percussion instrument. The waveform consists of a strong, fast rise-time "attack" followed by a gradual "decay." In the case of a bell, the attack is the initial high-amplitude sound produced when the bell is struck by its clapper. The decay is the ringing sound representative of the bell's natural resonant frequency.

Now that we've defined the frequency and amplitude relationships of the sounds we wish to simulate, we can start designing a circuit. Fortunately, our task is easy because "ringing," the effect we want to simulate, is a common and even pesky problem in many electronic circuits!

An active notch filter happens to make an excellent ringing circuit since it has a natural resonance frequency and can be adjusted to a critical point where oscillation can be externally stimulated and internally damped. As you may know, an active filter uses transistors or, better, one or more op amps to simulate a conventional filter. The active filter is superior to a passive filter since it has internal gain which replaces the losses of passive filters and since it can be made with a very high input impedance (very desirable) and a low output impedance (also very good).

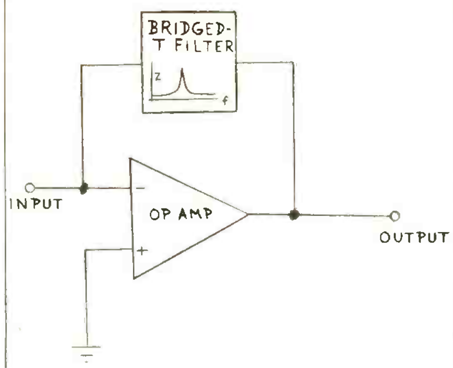

Fig. 2. Notch filter with maximum impedance at center frequency.

Figure 2 is the block diagram of a typical active notch filter which uses a single op amp, and Fig. 3 shows a working circuit. The filtering action takes place in the twin-T network formed by *R1*, *R2*, and their associated components. The twin-T notch filter is an old standby and is often used to block 60-Hz line noise in amplifiers and other circuits. The op amp provides restorative gain and interfacing to external circuits. You can operate the circuit as it is by connecting a miniature speaker to the output through a matching transformer (a unit with a 1000-ohm primary and an 8-ohm secondary), but you will have best results by connecting the circuit to an external audio amplifier.

The circuit works like this. The potentiometer is adjusted so that the filter just begins to oscillate and is then backed off until oscillation ceases. After this adjustment is made, a tiny input signal at pin 2 of the op amp will stimulate an oscillating attack followed by a gradual decay as the oscillation is dampened. How do you apply an input signal? Simple—just touch the touch plate (which can be a scrap of bare hookup wire) with a finger. The LM308, a precision op amp, has a typical input resistance of 40 megohms and readily accepts the small noise voltage from your body.

The frequency pattern of the circuit is very similar to Fig. 1, and the result is a very effective and realistic percussion simulator. You will probably have to make several adjustments of the pot for best results. If the circuit continues to oscillate without decaying, back off on the pot.

When *R1* and *R2* are about 100,000 ohms each, the circuit produces a very realistic bell sound when pin 2 is briefly touched. You can change the resonance frequency to simulate many other percussion instruments by

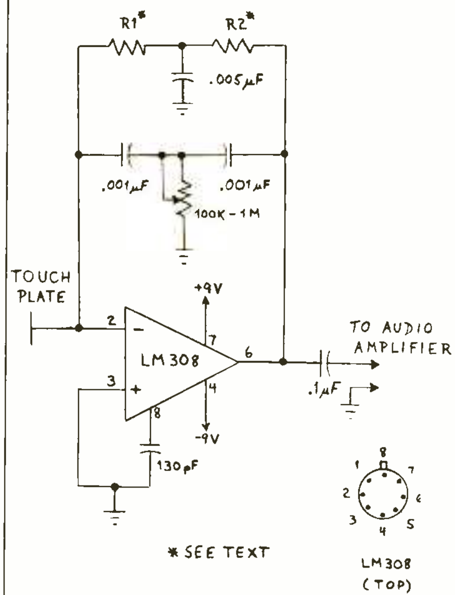

Fig. 3. Damped percussive waveform appears at filter output when touch plate is "struck."

changing *R1* and *R2*. Of course you will have to readjust the pot to obtain the best voice for each instrument. Try these values for various effects:

Instrument	R1 and R2
Triangle	33K
Small bell	47K
Medium bell	150K
Large bell	470K
Drum	1M

A narrow tuning range will help you adjust the circuit for optimum voicing, so you will want to use as small a value for the pot as possible. If 100,000 isn't enough, use values of up to 1M.

Incidentally, you can use various op amps in this circuit, but they may not respond to a touch input signal. If this occurs, just connect a resistance of a few thousand ohms between the positive power-supply lead and pin 2 of the op amp through a momentary contact spst (normally open) pushbutton switch. Press the switch to ring the bell, strike the drum, or whatever. For a ding-dong effect, insert a small (about 0.001-μF) capacitor in place of the resistor. Pressing the switch gives a sharp "ding" and releasing it gives a resonant "dong." This hookup makes a great doorbell circuit!

Finally, if this introductory project turns you on to electronic music, try building a complete percussion synthesizer from several filters adjusted to simulate various instruments. You can even build a realistic xylophone by building up a separate filter for each note. ◈