Solid State

By Lou Garner

CHIRP, JANGLE, WOOSH, BOOM!

A VERSATILE and unusual IC, virtually made-to-order for the experimenter and hobbyist, has been introduced by Texas Instruments, Inc., Box 84, Sherman, TX 75090. Designated the SN76477 complex sound generator, the new device is a monolithic IC combining both bipolar analog and I²L digital circuitry on a single silicon wafer. It includes basic circuit "blocks" which can be interconnected to produce an almost unlimited number of special sound effects ranging from a dog's bark or bird chirp to a gunshot or explosion. With the proper choice of external components, the SN76477 is capable of developing either familiar sounds such as a train whistle or futuristic sounds such as a "talking computer" or firing "phaser" ray gun. Offered in both standard 0.6-inch (1.5-cm) wide type N and the smaller 0.4-inch (1.0-cm) type NF 28-pin DIP's, the SN76477 can be powered by either a 5-volt regulated dc supply or well-filtered dc at 7.5 to 10.0 volts.

Not only is the SN76477 capable of producing a virtually unlimited variety of special sound effects, but the number of ways in which these may be used is limited only by the imagination and skill of the circuit designer and builder. In fact, a more experienced hobbyist might easily assemble a wide-range "Sound Effects Generator" by combining the SN76477 with a power amplifier, loudspeaker, and dc power supply. Such a project would also require multiple input and output jacks for the device terminals, potentiometers, various control switches, and a broad assortment of external components, selectable by means of appropriate rotary or toggle switches.

The functional block diagram of the new device is shown in Fig. 1. The SN76477 comprises a super-low-frequency (slf) oscillator, a programmable logic circuit permitting a choice of inputs to a voltage-controlled oscillator (vco), a noise clock, noise generator, noise filter, mixer, logic circuits for both systems inhibit and envelope selection, a one-shot, an envelope generator and modulator, an output buffer amplifier, and voltage regulator. Most of the circuits can be controlled or programmed externally by suitable components or signals. Circuit inputs identified with circles are programmed by using different capacitor values, squares identify programming by means of various resistors, triangles via logic levels and diamonds by analog voltages. Device pinout is shown in Fig. 2.

The slf oscillator has a nominal range of 0.1 to 30 Hz, depending on the R and C values used for programming, but can be used to generate frequencies as high as 20,000 Hz. It supplies two output signals, a 50% duty-cycle square wave which is applied to the Mixer and a triangle wave which can be routed to either an external vco or, through the SLF SELECT logic circuit, to the on-chip vco which can supply a fixed or frequency-modulated output over an almost 10:1 frequency range. Its lowest frequency is established by the values of the external resistor and capacitor connected to pins 18 and 17, respectively. The vco's output signal also is coupled to the mixer. A noise clock generates clock pulses to control the noise generator which, in turn, develops pseudo-random white noise that is applied through a variable-bandwidth, low-pass noise filter to the mixer. Accepting input signals from one or more sources (slf, vco, noise filter), the mixer performs a logical AND function and delivers the resulting signal to the envelope generator and modulator circuit. The mixer output is estab-

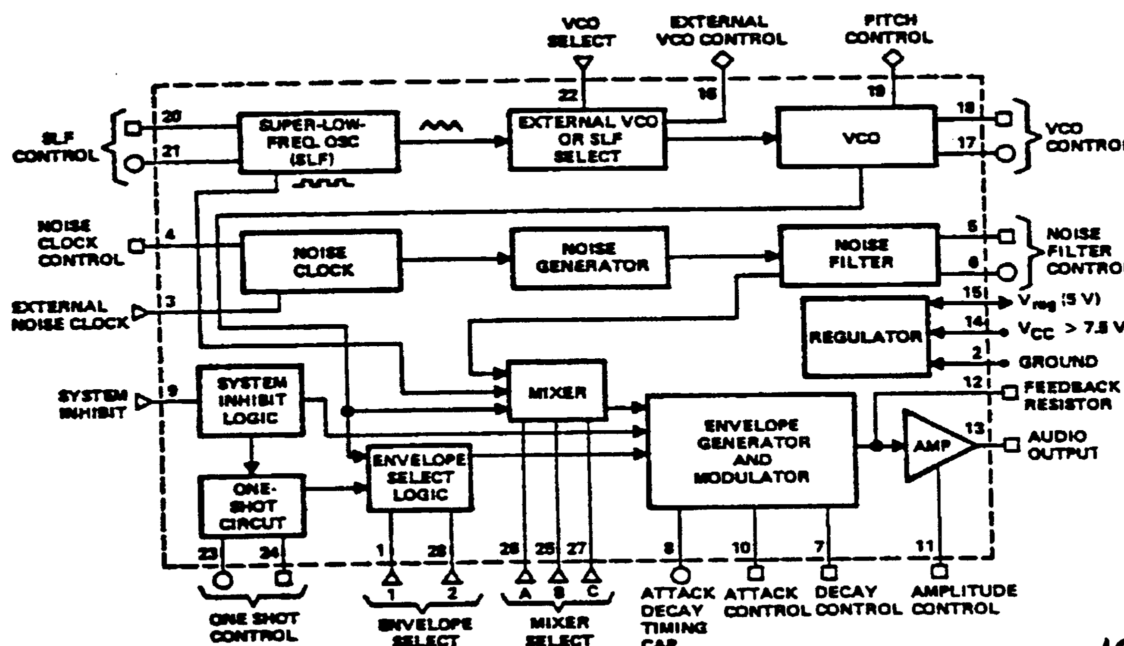


Fig. 1. Functional block diagram of Texas Instruments' new SN76477 Complex Sound Generator integrated circuit.

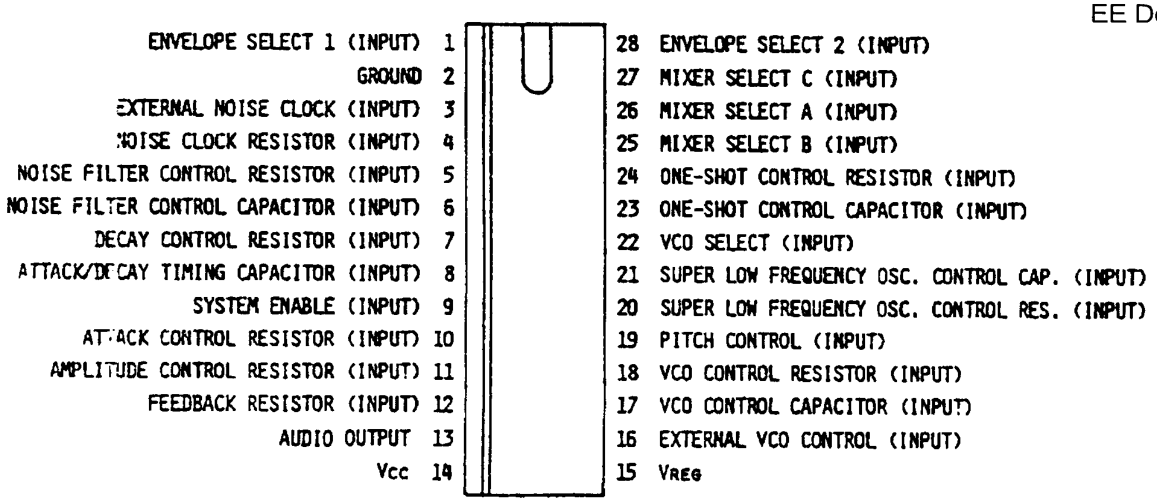


Fig. 2. Pin-out configuration and lead connections for the SN76477.

lished by the logic levels applied to its three SELECT terminals, pins 25, 26 and 27.

System inhibit logic circuit controls the system's output and also triggers a separate one-shot used to develop short-duration momentary sounds such as gunshots, bells or explosions. The duration of the one-shot's output is determined by the values of the control resistor and capacitor connected to pins 24 and 23, respectively, with the maximum period of approximately 10 seconds. The one-shot does not generate a sound signal itself, but is coupled through the envelope select logic circuit to the envelope generator and modulator, which provides an envelope for the signals from the mixer.

The envelope select logic circuit establishes the overall shape of the envelope which amplitude modulates the combined signal obtained from the mixer. Depending on the logic signals applied to ENVELOPE SELECT control pins 1 and 28, one of several operating modes can be selected, including vco, mixer only, one-shot, and vco with alternating cycles. The final shaping of the generated signal is performed by the envelope generator and modulator circuit, where the slf, vco, and filtered noise signals from the mixer are controlled by the system inhibit logic and modulated with the envelope established by the envelope select logic. This circuit also acts to modify the resulting signal's attack (rise time) and decay (fall time) characteristics.

Developing a maximum 2.5 volts, peak-to-peak, the output amplifier buffers the signal so that it can be applied to an external modulator or power amplifier. The buffer has a low output impedance. Finally, the regulator is designed to operate from *either* of two power sources. If available, 5 volts regulated dc can be applied to pin 15 (V_{REG}). Alternatively, 7.5 to 10 volts unregulated dc can be applied to pin 14 (V_{CC}), in which case the on-chip regulator will furnish a 5 V regulated output at up to 10 mA to power other circuits.

In summary, the SN76477 generates complex audio signal waveforms by combining the outputs of a low frequency oscillator, variable frequency (voltage controlled) oscillator, and noice source, modulating the resulting composite signal with a selected envelope and, finally, adjusting the signal's attack and decay periods. At each stage, the process can be controlled at the programming inputs of the signal modification and generation circuits, using control voltages, logic levels, or different resistor and capacitor values.

Representative signal waveforms developed during the process are illustrated in Fig. 3. The mixer output in the example shown in Fig. 3A is a variable-frequency signal containing filtered noise elements. This is modulated with a pulse envelope obtained from the one-shot and then shaped to form different types of sounds by altering the signal's attack and decay. In the second example (Fig. 3B), the mixer output is modulated by a repetitive pulse derived from the vco.

Different sounds are developed by varying the attack or decay, or both. The attack and decay can be modified by connecting different capacitor values to pin 8 and different resistor values to pins 10 and 7 which control the attack and decay, respectively.

Practical circuits featuring the SN76477 are illustrated in the figures. These were selected from among many circuits described in TI's data sheets. All feature a simple but effective audio amplifier to provide a low-level loudspeaker output and are designed for operation on a standard 9-volt transistor battery. At those points in the circuits where 5 V is required, it

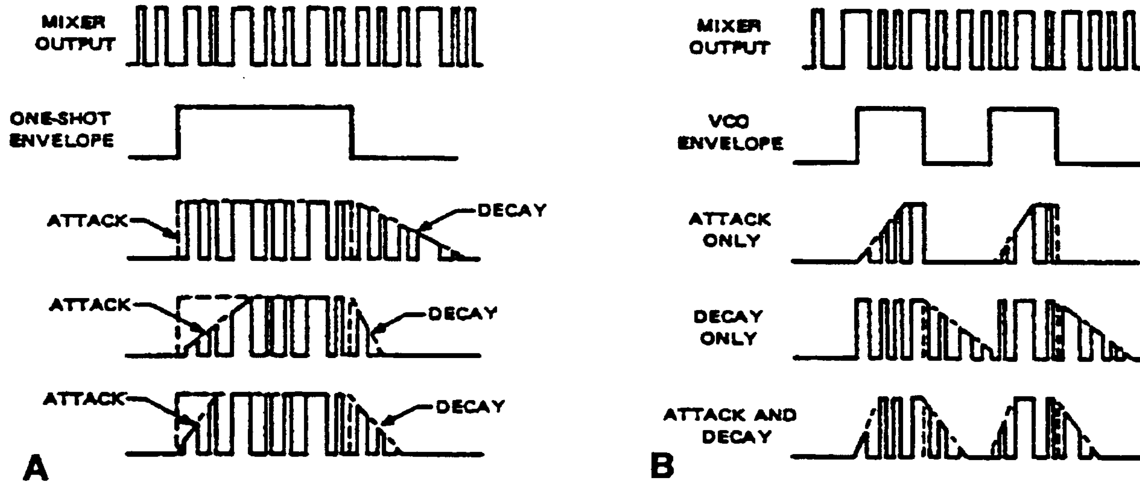


Fig. 3. Complex signal waveforms showing different attack and decay characteristics with (A) one-shot and (B) voltage-controlled oscillator modulation envelopes.

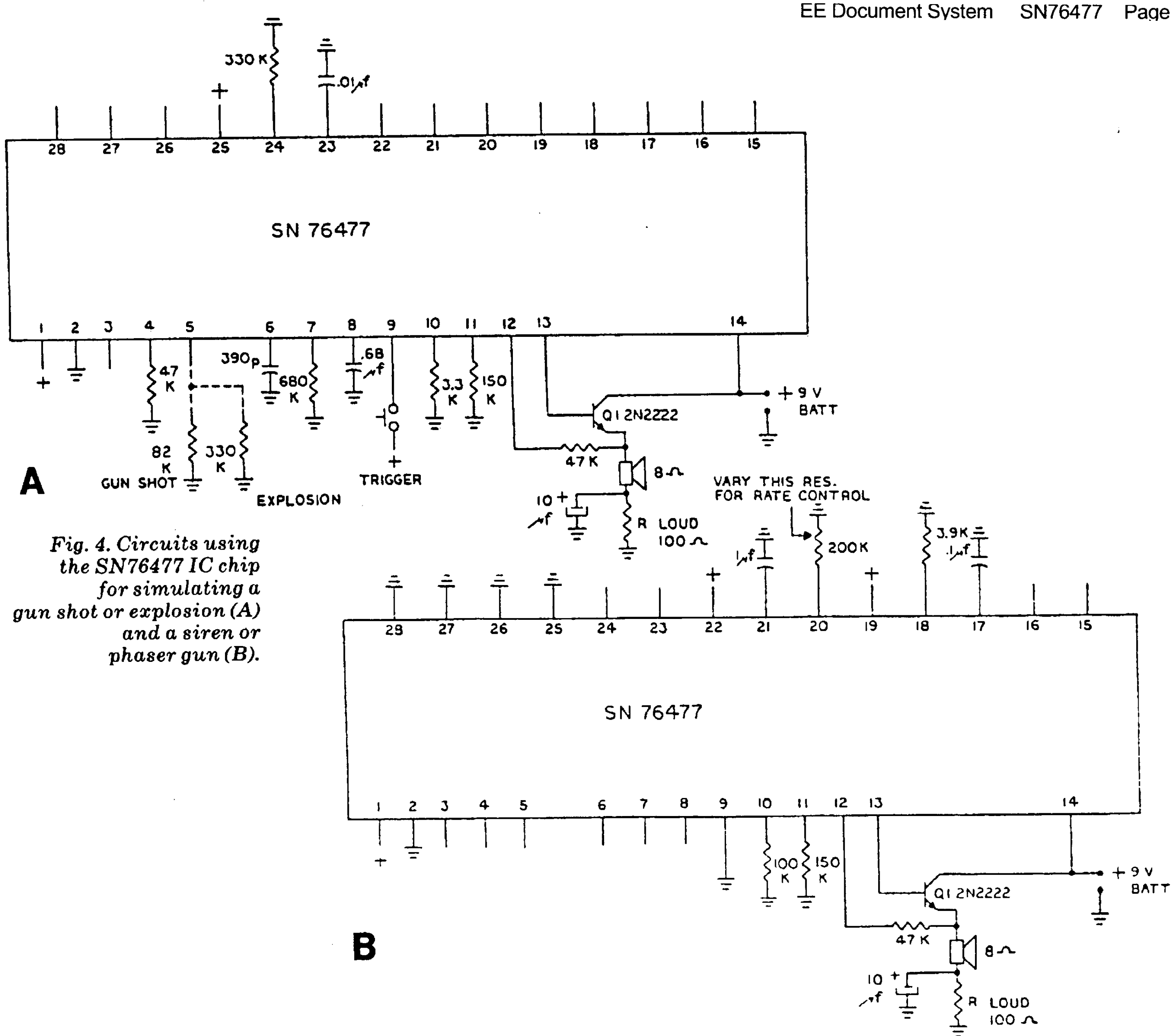


Fig. 4. Circuits using the SN76477 IC chip for simulating a gun shot or explosion (A) and a siren or phaser gun (B).

can be derived from pin 15 of the IC. All can be assembled using standard, readily available components. Except where potentiometers are specified, all resistors are either ¼- or ½-watt components. Small capacitors can be ceramic, plastic film, or tubular paper units; larger capacitances are 15-volt electrolytics.

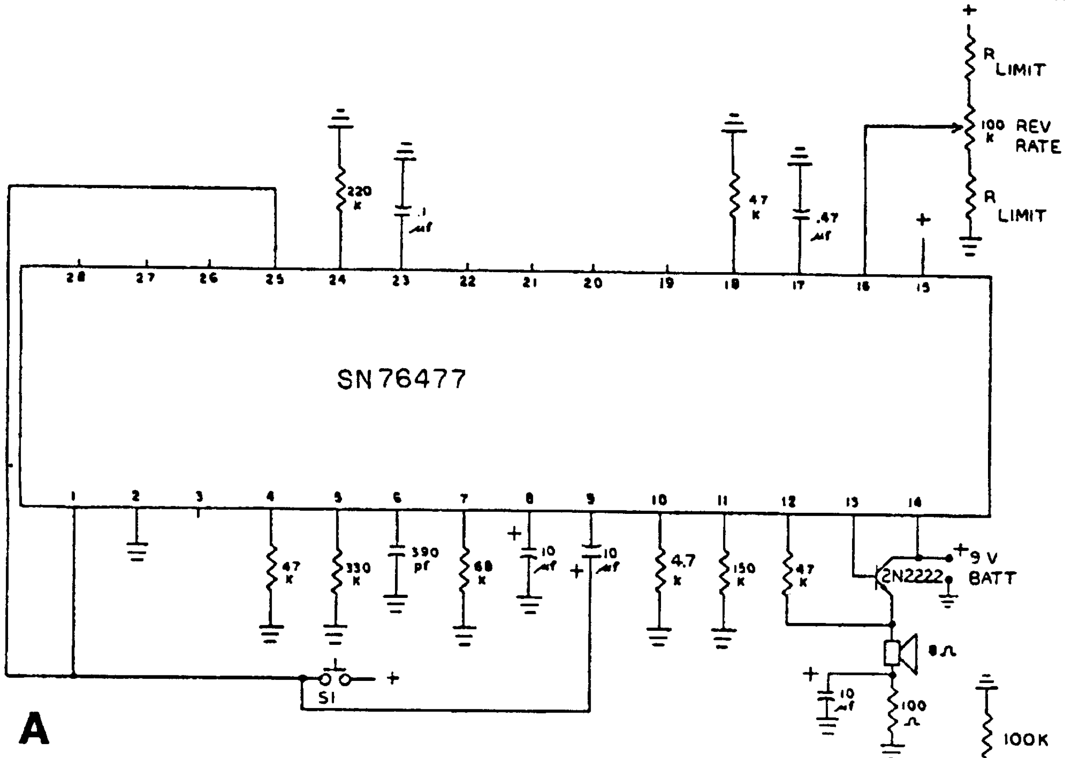
Neither layout nor lead dress are critical in any of the circuits, which can be duplicated using a solderless breadboard, perforated or printed circuit board. The usual precautions should be observed when soldering to avoid overheating the semiconductors, and all polarities must be observed.

When duplicating a normally loud sound such as a gunshot or explosion, it will be necessary to couple the circuit to a high-power audio amplifier driving a large loudspeaker. However, a 4-to-6-inch (10.2-to-15.3-cm) loudspeaker and the push-pull amplifier shown in the schematics should be adequate for most applications.

Designed to simulate the sounds of either a gunshot or explosion, the circuit shown in Fig. 4A is triggered by applying a 5-volt pulse through a momentary-contact, normally open pushbutton switch to the system inhibit logic and one-shot circuits (pin 9). The 5-volt dc level required here as well as for the envelope select logic (pin 1) and mixer select (pin 25) is obtained from the IC's V_{REG} output (pin 15). Different resistor values are used to program the noise filter circuit (pin 5) to simulate the two sounds, (82,000 ohms for a gunshot and 330,000 ohms for an explosion).

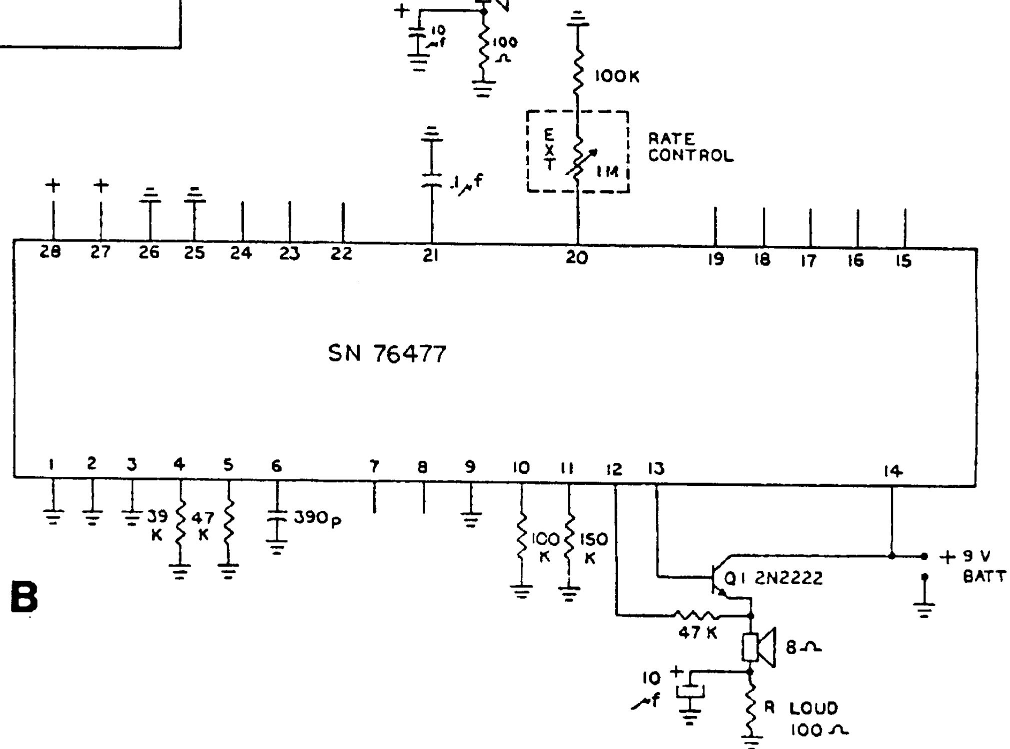
Several different sounds can be simulated by the circuit shown in Fig. 4B, including a siren, space war, or "phaser" gun, depending on the adjustment of the 200,000-ohm RATE CONTROL potentiometer. For increased realism, the IC's one-shot (pins 9, 23, 24) and decay (pins 8, 7) functions can be implemented. As before, +5 volts dc needed for pins 1, 19, 22 is obtained from V_{REG} (pin 15).

Circuits for simulating the sounds of a racing car motor or crash and a chugging steam engine or reciprocating airplane engine are shown in Fig. 5A and 5B, respectively. In the first circuit, the racing car motor's rev rate is adjustable by means of a 100,000-ohm potentiometer which varies the dc voltage applied to the external vco control input (pin 16). The maximum and minimum rev rates are set by fixed resistors in series with the potentiometer. A crashing sound is initiated by



A

Fig. 5. Two circuits using the SN76477: (A) simulating a racing car's rev rate or a crashing sound; and (B) a chugging steam engine or reciprocating airplane.



B

depressing a spst normally open pushbutton switch, which applies a voltage pulse through a 10-µF capacitor to the system inhibit logic and one-shot circuits (pin 9), simultaneously changing the envelope select (pin 1) and mixer select (pin 25) settings.

In the second circuit, the slf oscillator frequency is controlled by a 1-megohm potentiometer connected to one of its programming input (pin 20). As this RATE CONTROL is adjusted from a very low to a moderately low frequency, the generated sound is like that of a steam engine gradually increasing in speed. At higher frequencies, the sound approximates that of a propeller-driven airplane.

From a technical viewpoint, there's virtually no limit to the number and types of sounds that can be generated using one, two, three or more SN76477 IC's in conjunction with multiplexing and external programming networks. By using programmable analog switches to select outputs from different units, for example, a clever experimeter easily could create circuits to generate background jungle noises, night sounds, complete battlefield or eerie haunted-house sounds, or even musical selections interspersed with unusual sound effects. In commercial and industrial alarm applications, different sounds could be used to identify various danger conditions, such as illegal entry, fire, basement flooding, or power failure. The IC's are available through TI franchised dealers and are relatively inexpensive. The rest is up to your imagination!

Reader's Circuit. Alan Peter Allegra (218 11th Ave., Bethlehem, PA 18018) was intrigued with J. Fortuna's "Digistart" project in our column of April 1977. One of his friends, Frank Resul, had designed a "combination lock" digital ignition switch for his '75 VW sometime earlier.

SN76477N COMPLEX SOUND GENERATOR

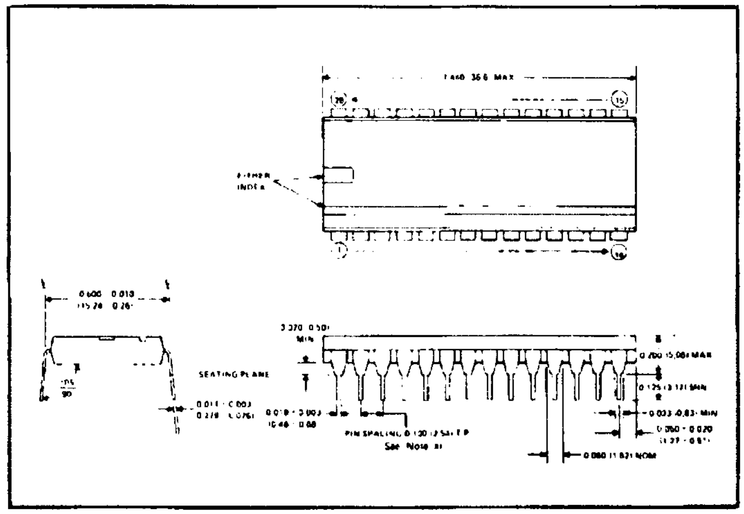
DESCRIPTION:

The SN76477N Complex Sound Generator is a linear/I^2L device which provides noise-, tone- or low-frequency - (or a combination of these) based complex sounds. Programming is via external components, (user-selected), which allows a wide variety of sounds to be created. The SN76477N is designed for ultimate flexibility in user-defined sounds, and may be used in any application requiring audio feedback to the operator (i.e. arcade/home video games, pinball games, toys, etc.; consumer oriented equipment, such as timers, alarms, controls, etc.; industrial equipment for indicators, alarms, feedback controls, etc.).

FEATURES

- Generates Noise, Tone or Low-Frequency-Based Sounds, or Combination of These
- Allows Custom Sounds to be Created Easily
- Low Power Requirements
- Allows Multiple-Sound Systems
- Compatible With Microprocessor Systems

OUTLINE DIMENSIONS



ABSOLUTE MAXIMUM RATINGS AT TA = 25°C (UNLESS OTHERWISE SPECIFIED)

Supply Voltage, VREG, Pin 15 .... 6.0V
Supply Voltage, VCC, Pin 14 .... 12.0V
Input Voltage Applied to any Device Terminal 6.0V
Operating Temperature Range .... −55°C to +120°C
Lead Temperature 1/16 Inch From Case For 10 Seconds ... +260°C

RECOMMENDED OPERATING CONDITIONS

	MIN.	TYP	MAX	UNITS
Supply Voltage, VREG, Pin 15	4.5	5.0	5.5	V
Supply Voltage, VCC, Pin 14	7.5		9.0	V
Operating Free-Air Temperature	0	25	70	°C

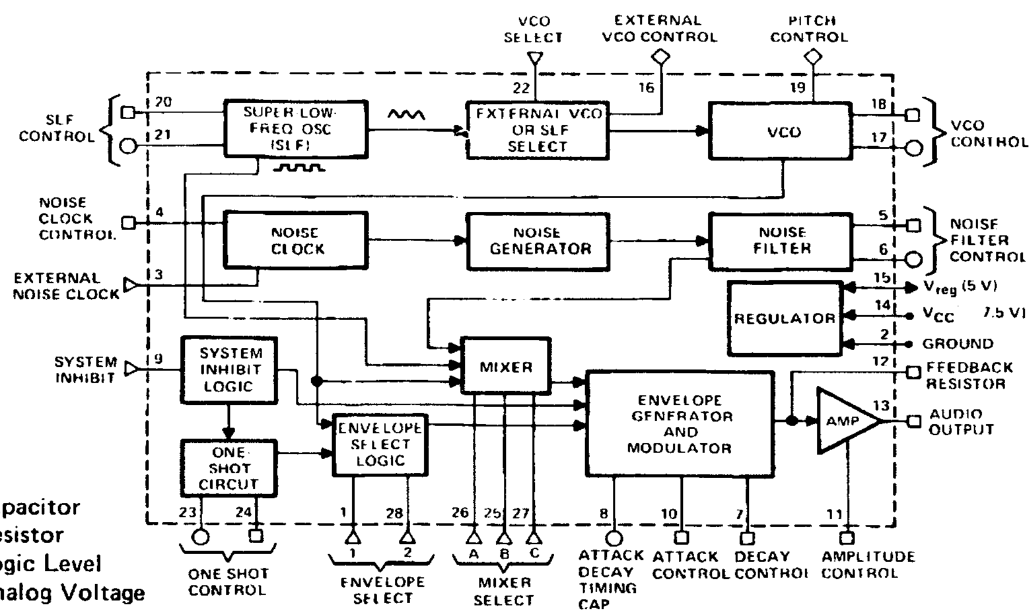
DUAL-IN-LINE PACKAGE (TOP VIEW)

ENVELOPE SELECT 1 (INPUT)	1	28	ENVELOPE SELECT 2 (INPUT)
GROUND	2	27	MIXER SELECT C (INPUT)
EXTERNAL NOISE CLOCK (INPUT)	3	26	MIXER SELECT A (INPUT)
NOISE CLOCK RESISTOR (INPUT)	4	25	MIXER SELECT B (INPUT)
NOISE FILTER CONTROL RESISTOR(INPUT)	5	24	ONE-SHOT CONTROL RESISTOR (INPUT)
NOISE FILTER CONTROL CAPACITOR (INPUT)	6	23	ONE-SHOT CONTROL CAPACITOR (INPUT)
DECAY CONTROL RESISTOR (INPUT)	7	22	VCO SELECT (INPUT)
ATTACK/DECAY TIMING CAPACITOR (INPUT)	8	21	SUPER LOW FREQUENCY OSC. CONTROL CAP. (INPUT)
SYSTEM ENABLE (INPUT)	9	20	SUPER LOW FREQUENCY OSC. CONTROL RES. (INPUT)
ATTACK CONTROL RESISTOR (INPUT)	10	19	PITCH CONTROL (INPUT)
AMPLITUDE CONTROL RESISTOR (INPUT)	11	18	VCO CONTROL RESISTOR (INPUT)
FEEDBACK RESISTOR (INPUT)	12	17	VCO CONTROL CAPACITOR (INPUT)
AUDIO OUTPUT	13	16	EXTERNAL VCO CONTROL (INPUT)
VCC	14	15	VREG

OPERATING CHARACTERISTICS AT TA = 25°C AND VREG = 5.0V

PARAMETER	PIN	CONDITIONS	MIN	TYP	MAX	UNITS
ICC	14	VREG = 5.0V; NO EXT. LOAD		15	40	MA
VREG	15	VCC = 8.25V; I_{LOAD} = 10MA	4.5		5.5	V
INPUT REGULATION	15	I_{LOAD} = 10MA VCC = 7.5V TO 9.0V		150		MV
CONTROL INPUT CURRENT RANGE			1		200	uA
NOISE CLOCK	4					
NOISE FILTER	5					
DECAY	7					
ATTACK	10					
AMPLITUDE	11					
VCO	18					
ONE SHOT	24					
LOGICAL "1" INPUT CURRENT						
ENVELOPE SELECT 1 & 2	1, 28	@ 2.0V		40	52	uA
MIXER SELECT A, B, C	25, 26, 27	@ 2.0V		40	52	uA
VCO SELECT	22	@ 2.0V		40	52	uA
EXTERNAL NOISE	3	@ 2.0V		40	52	uA
SYSTEM ENABLE	9	@ 2.0V			100	uA
LOGICAL "1" INPUT VOLTAGE			2.0			V
ENVELOPE SELECT 1 & 2	1, 28					
MIXER SELECT A, B, C	25, 26 27					
VCO SELECT	22					
EXTERNAL NOISE	3					
SYSTEM ENABLE	9					
LOGICAL "0" INPUT VOLTAGE					0.8	V
ENVELOPE SELECT 1 & 2	1, 28					
MIXER SELECT A, B, C	25, 26 27					
VCO SELECT	22					
EXTERNAL NOISE	3					
SYSTEM ENABLE	9					
EXTERNAL VCO CUTOFF	16		2.5			V
TRIP POINTS				2.5		V
ONE-SHOT CAP	23					
VCO CAP	17					
NOISE FILTER CAP	6					
SLF CAP	21					
MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE SWING	13	R_{LOAD} = 10K R_{FDBK} = 10K I_{11} = 200uA	2.5			V
DYNAMIC OUTPUT IMPEDANCE	13			100		OHMS

BLOCK DIAGRAM:



○ Denotes Programming Via Capacitor
□ Denotes Programming Via Resistor
△ Denotes Programming Via Logic Level
◇ Denotes Programming Via Analog Voltage

OPERATION

1. SLF (SUPER LOW FREQUENCY OSCILLATOR)

The SLF is normally operated in the range of 0.1 – 30 Hz, but will operate up to 20 kHz. The frequency is determined by the SLF control resistor (Pin 20) and capacitor (pin 21) according to the following equation:

$$\text{SLF Frequency (Hz)} \approx \frac{0.64}{R_{SLF}\, C_{SLF}} \quad @\ V_{REG} = 5.0V$$

Equation 1: SLF Frequency Equation

The SLF feeds a 50% duty cycle square wave to the "mixer"; it also feeds a triangular wave to the "ext. VCO/SLF Select" logic, which is fed through to control the VCO when Pin 22 is high (see further explanation below).

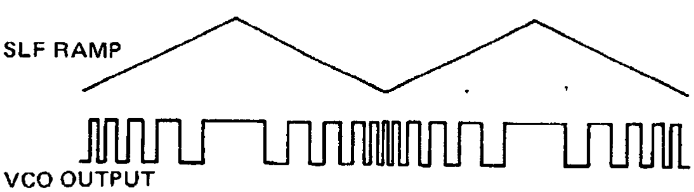
2. VCO (VOLTAGE CONTROLLED OSCILLATOR)

The VCO circuitry produces a tone output whose frequency is dependent upon the voltage at the input of the VCO. The higher Pin 16 voltage is, the lower the frequency. The controlling voltage may be either the SLF output, or it may be an externally applied signal on Pin 16. The selection of control modes (external – Pin 16; internal – SLF) is via the binary logic level on Pin 22, VCO Select, according to the following table:

Pin 22	Control Mode
0	External (Pin 16)
1	Internal (SLF)

Table 1: VCO Control Mode Selection

The input at the External VCO Control Pin 16, may be a DC voltage, (producing a constant tone at the output of the VCO), or any waveform, producing a frequency modulated output from the VCO. A frequency modulated waveform also results when the SLF ramp controls the VCO (Pin 22 = high), as shown below:



VCO FM output

An alternate method to apply an external voltage to the VCO input is to place the controlling voltage on the SLF Control Capacitor Pin (Pin 21). In some applications this may be more convenient than using the Pin 16 input. The frequency Range of the VCO is internally determined at an approximate ratio of 10:1. The minimum frequency of the VCO may be determined by adjusting the RC time-contant of the VCO Control Resistor (Pin 18) and the VCO Control Capacitor (Pin 17), according to the following equation:

$$\text{Min VCO Freq. (Hz)} \approx \frac{0.64}{R_{VCO}\, C_{VCO}} \quad @\ V_{REG} = 5.0V$$

Equation 2: Minimum VCO Frequency

The Pitch Control (Pin 19) varies the duty cycle of the VCO output according to the following equation:

$$\text{VCO Duty Cycle} \approx 50 \times \frac{\text{Voltage at Pin 16}}{\text{Voltage at Pin 19}} \ \%$$

Equation 3: Pitch Control of VCO Duty Cycle

By leaving Pin 19 high, a constant 50% duty cycle may be achieved. The specific % duty cycle, applies to constant tones produced by applying a constant DC voltage at the External VCO Control Pin (Pin 16). However, the Pitch Control may still be used to aesthetically alter the pitch of any frequency-modulated VCO output signals.

3. NOISE CLOCK

The Noise Clock clocks the Noise Generator. This circuit requires a 43K resistor to ground at Pin 14 to set an internal current level. An external noise clock may be supplied at Pin 3 to allow generation of lower frequency noise. This external clock should be a maximum 5 volt peak-to-peak square wave.

4. NOISE GENERATOR/FILTER

The Noise Generator is a binary psuedo random white noise generator whose output passes through the Noise Filter before being inputed to the mixer. The filter is a variable band width low-pass filter whose 3dB point is defined by the following equation:

$$\text{3dB Frequency (Hz)} \approx \frac{1.28}{R_{NF}\, C_{NF}} \quad @\ V_{REG} = 5.0V$$

Equation 4: Noise Waveform 3 dB Frequency

5. The Mixer Logic selects one, (or a combination), of the inputs from the generators and feeds the output to the Envelope Generator and Modulator.

Mixer Select			Mixer Output
C (Pin 27)	B (Pin 25)	A (Pin 26)	
0	0	0	VCO
0	0	1	SLF
0	1	0	Noise
0	1	1	VCO/Noise
1	0	0	SLF/Noise
1	0	1	SLF/VCO/Noise
1	1	0	SLF/VCO
1	1	1	Inhibit

Table 2: Mixer Select Logic

6. SYSTEM ENABLE LOGIC

The System Enable Logic provides an enable/inhibit for the system output. The sound output is controlled according to the following table:

Pin 9	Output
0	Enabled
1	Inhibited

Table 3: System Enable Logic

This input also triggers the "one-shot" logic for momentary sounds, such as gunshots, bells and/or explosions. The "one-shot" logic is triggered by the negative-going edge. This may be accomplished by a momentary switch, or by a square wave input at Pin 9. Pin 9 must be held low for the entire duration of the one-shot sound (including attack and decay period). The one-shot logic is operable only when the proper Envelope Select Logic selection is made. (see Envelope Select Logic).

7. "ONE-SHOT" LOGIC

The duration of the "one-shot" is defined by the following equation:

$$\text{Duration (seconds)} \approx 0.8\, R_{OS}\, C_{OS} \quad @\ V_{REG} = 5.0V$$

Equation 5: One-Shot Duration

In Equation 5, ROS is the One-Shot Control Resistor (Pin 24) and COS is the One-Shot Control Capacitor (Pin 23). Maximum duration of the One-Shot is approximately 10.0 seconds. When the One-Shot is controlled by external logic, the One-Shot Control Resistor and Capacitor may be eliminated. Simply begin One-Shot with Pin 9 (system enable) and end cycle by taking Pin 23 (One-Shot Capacitor) high.

8. ENVELOPE SELECT LOGIC

The Envelope Select Logic determines the envelope that is applied to the mixer output according to the following table

Envelope Select 1	Envelope Select 2	Selected Function
Pin 1	Pin 28	
0	0	VCO
0	1	Mixer Only
1	0	One-Shot
1	1	VCO with Alternating Polarity

Table 4: Envelope Select Logic Output

9. ATTACK AND DECAY CONTROL

The Attack/Decay circuitry alters the rise and fall of the envelope. An example of a noise waveform utilizing the envelope generator under one-shot control is:

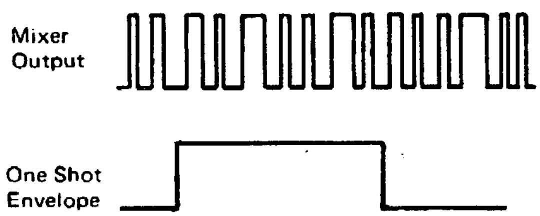


Figure 4: One-Shot Controlled Noise Waveform

By utilizing the Attack and Decay Control Inputs (Pin 7,10), the waveform may be affected in the following manner:

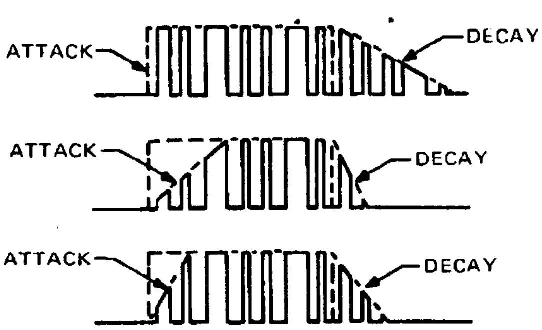


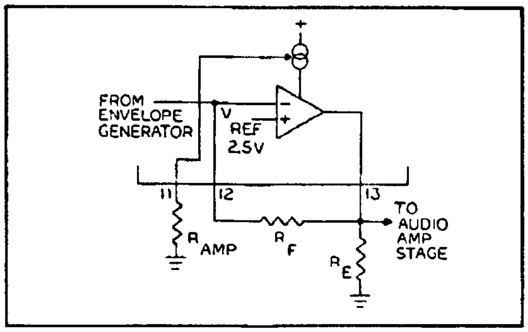
Figure 5: Examples of Varying Degrees of Attack and Decay on a Waveform

The amount of Attack and Decay is determined by the Attack Control Resistor (RA) (Pin 10) and the Decay Control Resistor (RD) (Pin 7) and the Attack Decay Timing Capacitor (CA-D) (Pin 18) According to the following equations:

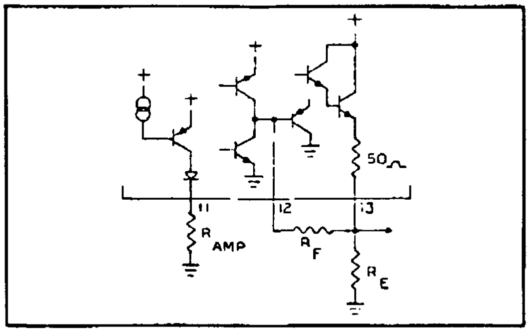
$$\text{Attack Time (seconds)} \approx R_A C_{A-D}$$
$$\text{Decay Time (seconds)} \approx R_A C_{A-D}$$
$$@ \; V_{REG} = 5.0V$$

10. OUTPUT AMPLIFIER

The output amplifier is a gain section designed to interface with external sound modulators or additional amplifier stages. The output is an operational amplifier operating as a summer and invertor, as illustrated. The output is an emitter-follower without a load resistor. Therefore, pin 13 should have a pull-down resistor, RE, with a value ranging from 2.7K to 10K ohms. The equivalent of the input circuitry for the amplifier section is shown in the next column.



Operational Amplifier



Operational Amplifier Internal Input Circuitry

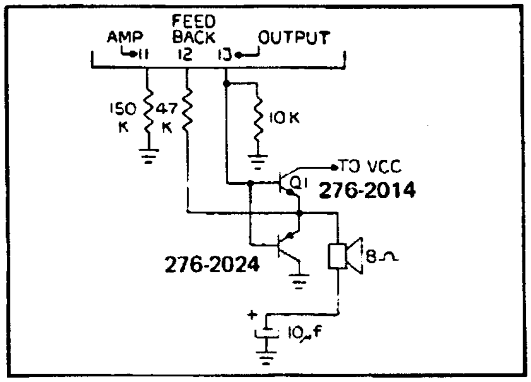
The resistor value RAMP sets the operating currents for the operational amplifier's internal circuitry and is the main adjustment to control the amplifier's output amplitude. The value of this resistor is normally between 47K and 220K ohms. Any lower resistance will typically begin to saturate the operational amplifier and is especially noticeable on the decay portion of the sound envelope.

The feedback resistor, RE, is used to compensate for external variations and also any chip-to-chip variations. This is accomplished by connecting the feedback resistor between the last amplifier stage and the input Pin 12, as shown below. The feedback resistor is connected to the last stage at a point where the signal is in-phase with the operational amplifier's output. The peak output voltage is determined by the following equation:

$$V_{OUT} \approx \frac{3.4R_F}{R_{AMP}} \qquad @ \; V_{REG} = 5.0V$$

Where VOUT = volts
R = ohms

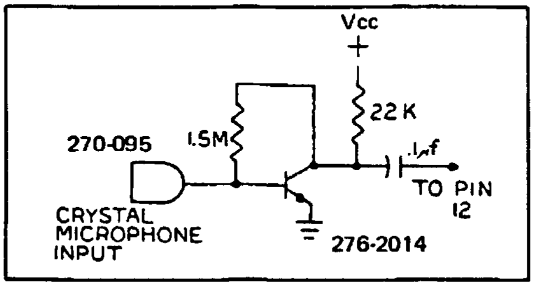
The dynamic output range is limited to 2.5 volts peak-to-peak before clipping occurs. The example shown is ideally suited for most applications. The amplifier is in a push-pull configuration and will draw current only when a signal is present. Depending on the voltage applied to the collector of Q1, this circuit will provide approximately 300-400mW of power into an 8-ohm speaker.



If the amplitude of the sound output is to be varied for particular sounds, the resistance RAMP can be varied by logic control lines. This can be done (as described earlier) by using the logic control line to switch a logic gate that will put a resistor in parallel with RAMP.

Special filtering can be added to the output of the amplifier or can be included in the feedback section of the operational amplifier. Since the output of the amplifier always contains square waves, filtering will change the timbre (harmonic content) of the output signal.

Other external sounds may be added to the input of the amplifier at Pin 12. This input can be made either directly or through a series resistor. An example of an input configuration to add a person's voice to the system is shown below. This could be used to sing along or talk along with the sounds being generated by the chip.



11. REGULATOR

Either a 5-volt regulated supply may be applied to Pin 15 (VREG) or a 7.5-volt min/9.0 volt max regulated supply may be applied to Pin 14 (VCC). Pin 15 (VREG) can be used as a 5-volt regulated supply for the rest of the system with a current supply of up to 10MA out of the IC.

12. NOTE:

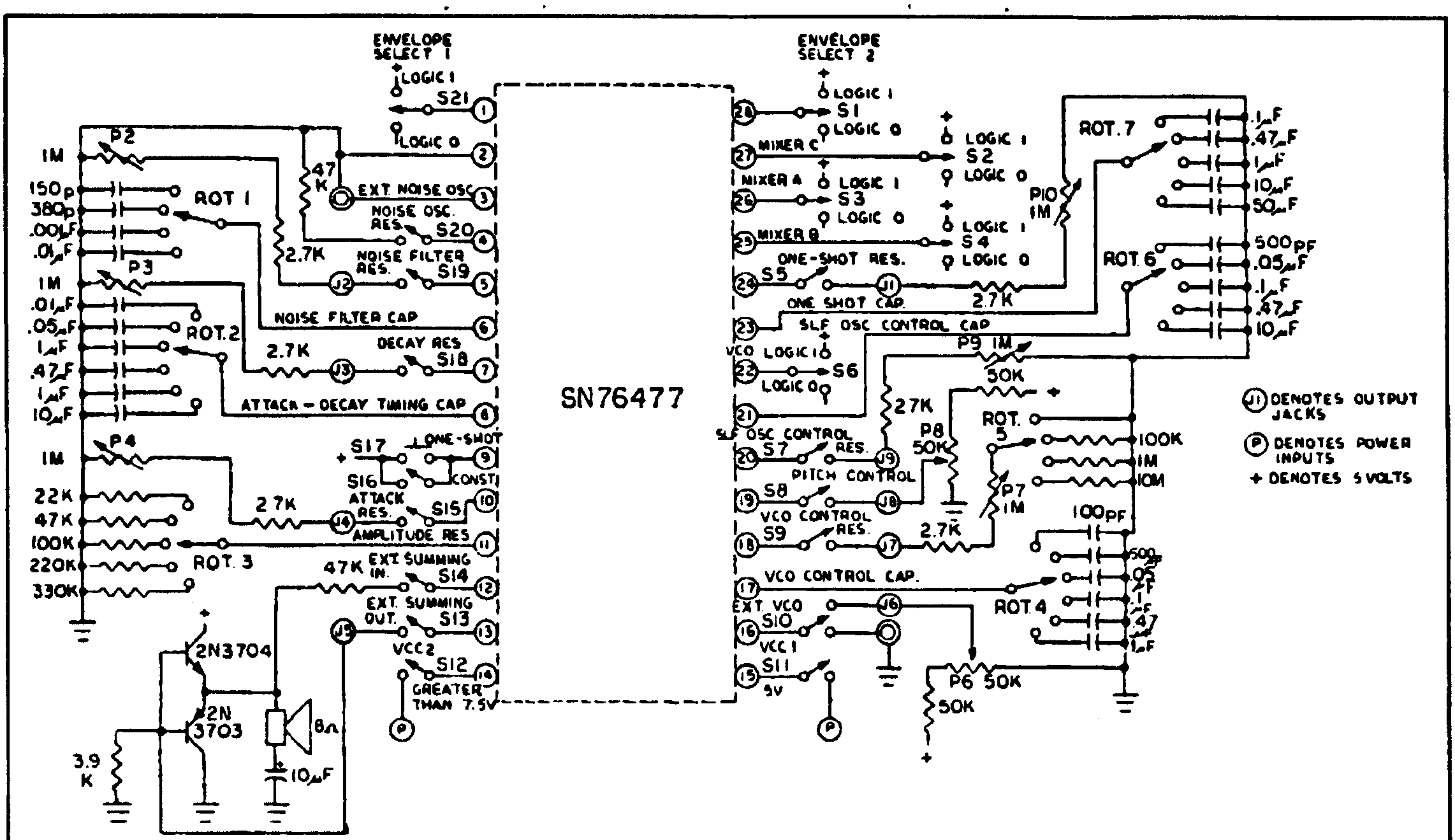
Control resistors and capacitors may be eliminated if the desired sound does not require that generator or logic section. For dedicated sound, the logic inputs (Pins 1, 9, 22, 25, 26, 27, 28) may be hard-wired for high or low logic levels. Individual sounds (single or multiple) will determine which of the other components are required.

DESIGN SEQUENCE FOR DEVELOPING COMPLEX SOUND

An approach to designing custom complex sounds will be illustrated and discussed in this section. These steps may vary depending on your particular applications for the IC.

The first step is to build a "sound demonstrator box" similar to the one shown below. This is a time-saving step and will aid in analyzing and understanding each section of the chip, help in determining what sounds are desired, and in determining the component values to obtain those sounds. The demonstrator box typically requires a couple of days for a technician to build. If portable operation is desired, a 9-volt battery may be used for a power source.

The next step is to check out each section of the IC using the demonstrator box.



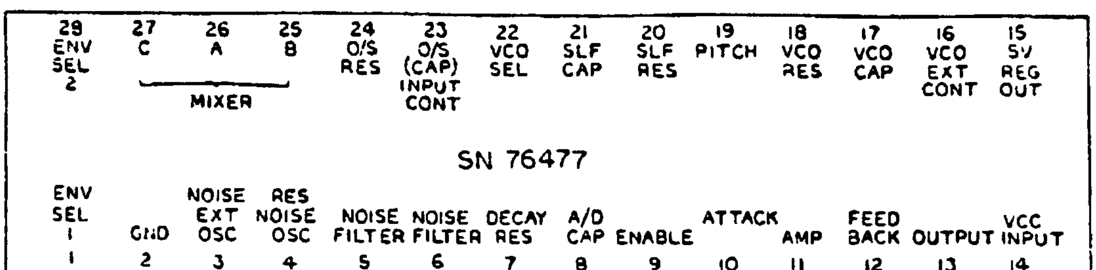
The third step is to choose a simple sound, such as a tone or noise only, and approach the reproduction of that sound scientifically. For example, suppose a gun-shot sound is chosen. It requires noise, one-shot timing and attack/decay. Therefore, program the envelope select for one-shot timing and attack/decay. Therefore, program the envelope select for one-shot operation, and noise should be selected for the mixer's output. The attack time should be rapid, which suggests that the attack resistance must be at a minimum value. The gun-shot requires some decay, so the resistance used will have to be adjusted while firing the one-shot and listening to determine the correct length. The one-shot's RC timing should be short. However, if it is too short, the sound output will never have time to provide the necessary amplitude to the output amplifier. Therefore, the one-shot's RC values must be adjusted longer than expected and then be decreased to the desired length. Finally, the noise filter's RC network should be adjusted for the desired gun-shot noise.

Step four requires logging the component values and logic levels used in your sound for future reference. The table below shows a sound logging table including values for the gun shot example. This step is very important since it will keep a log of interesting sounds and prevent the wasted time of trying to repeat an identical sound you have produced in the past. All component values can be determined from the "demonstrator box". Use an ohmmeter to measure required resistor values by connecting it to a particular sound section's resistor jack and opening the switch that is in series with the IC. The capacitor values are determined from the labels on your demonstrator box.

	GUNSHOT						
RESISTORS							
Decay	680K						
Attack	4.7K						
Amplitude	150K						
One-Shot	330K						
VCO	–						
Filter	82K						
SLF	–						
Pitch	–						
VCO Ext	–						
LOGIC CONTROL							
Env 1	1						
Env 2	0						
Mixer A	0						
Mixer B	1						
Mixer C	0						
VCO Select	-						
CAPACITORS							
One-Shot	.01						
SLF	–						
VCO	–						
Filter	390p						
Attack/ Decay	.68						

Table: Complex Sound Log

Step five is to draw the schematic needed to generate this particular sound. If copies of the IC's pinout are made, similar to the one shown here, your time is devoted only to drawing in the necessary external component values.



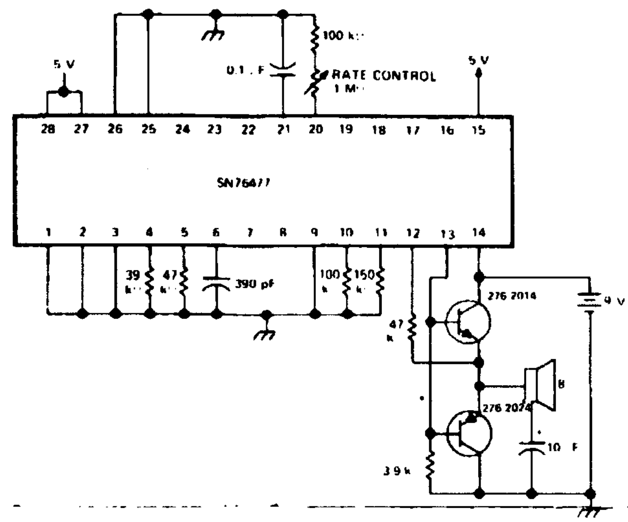
IC Pinout

Step six requires a breadboard of the circuit. Then make any necessary adjustments to the component values.

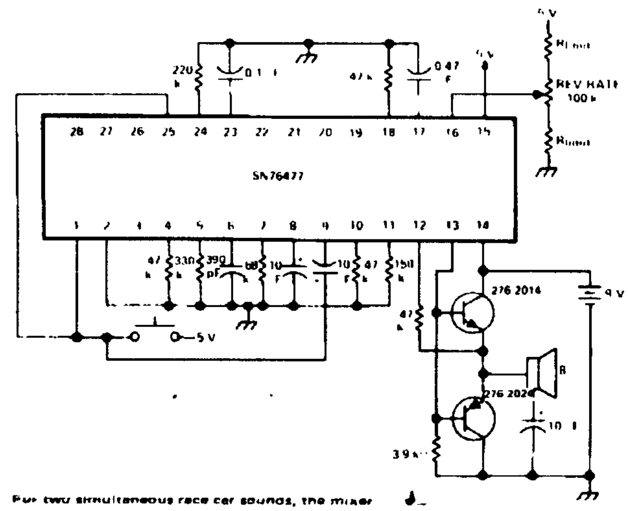
Step seven is used when several sounds that you have developed (through steps three to five) need to be combined. Compare each individual sound schematic produced in step five. Select all common components on each circuit and draw this on another IC pinout copy. Then determine if any differing values may be compromised to the same value as that used in another sound. For example, if a gun-shot was determined to have a certain set of RC one-shot values, and a ricochet had another set, then could there be a compromise between the two which would make one set common to both? Decide on the type of switching logic you will need to switch between sounds, plus any component additions and add to this drawing.

In step eight, this preliminary system should be bread-boarded. Then each sound should be adjusted until that sound is satisfactory.

TYPICAL APPLICATIONS

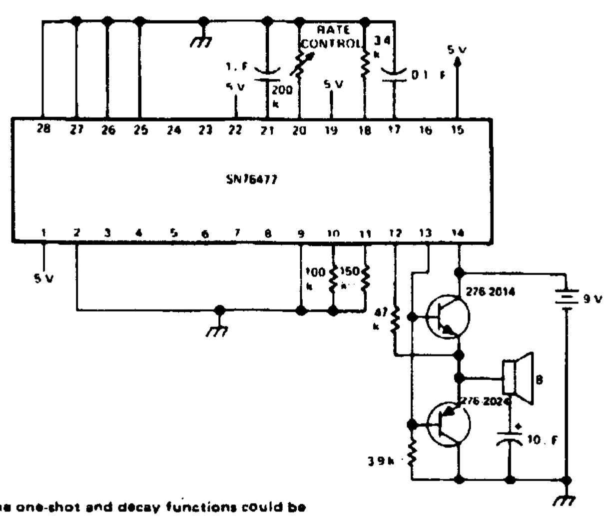


STEAM TRAIN/PROP PLANE



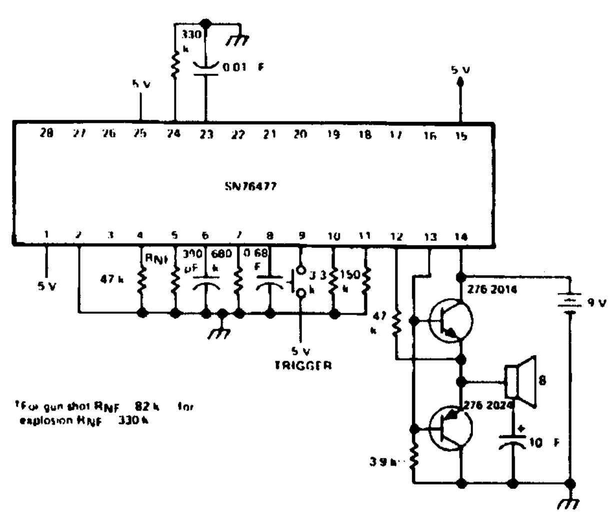
For two simultaneous race car sounds, the mixer can be multiplexed between the SLF and VCO functions.

RACE CAR MOTOR/CRASH



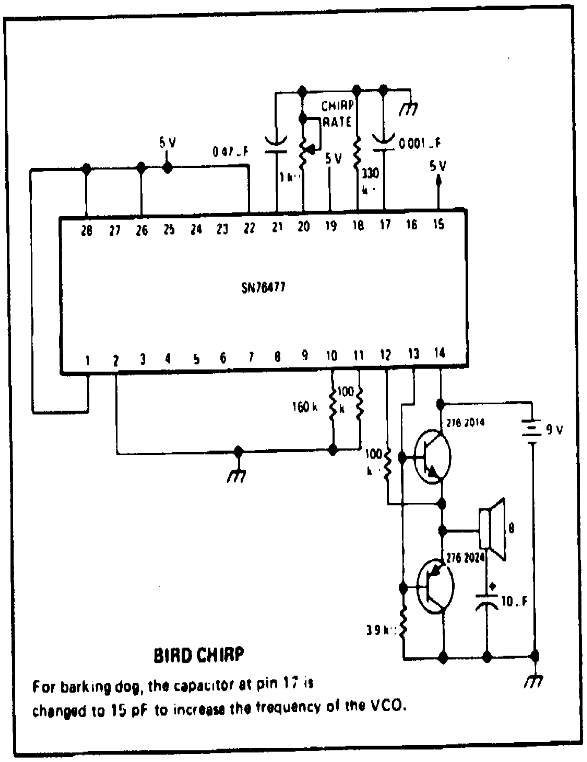
The one-shot and decay functions could be added to make an ideal phasor gun sound.

SIREN/SPACE WAR/PHASOR GUN



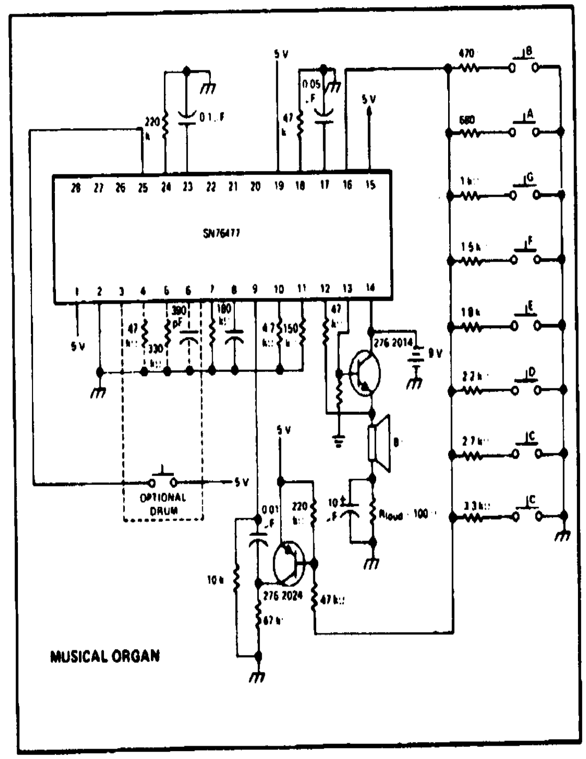
†For gun shot RNF 82 k for explosion RNF 330 k

GUNSHOT/EXPLOSION

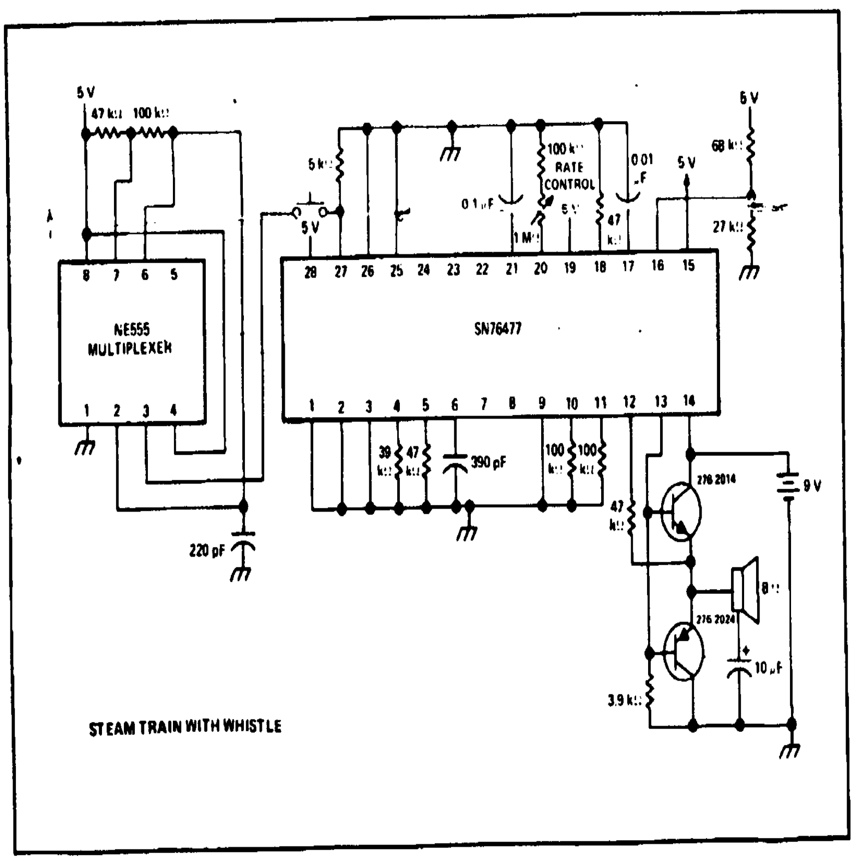


BIRD CHIRP

For barking dog, the capacitor at pin 17 is changed to 15 pF to increase the frequency of the VCO.



MUSICAL ORGAN

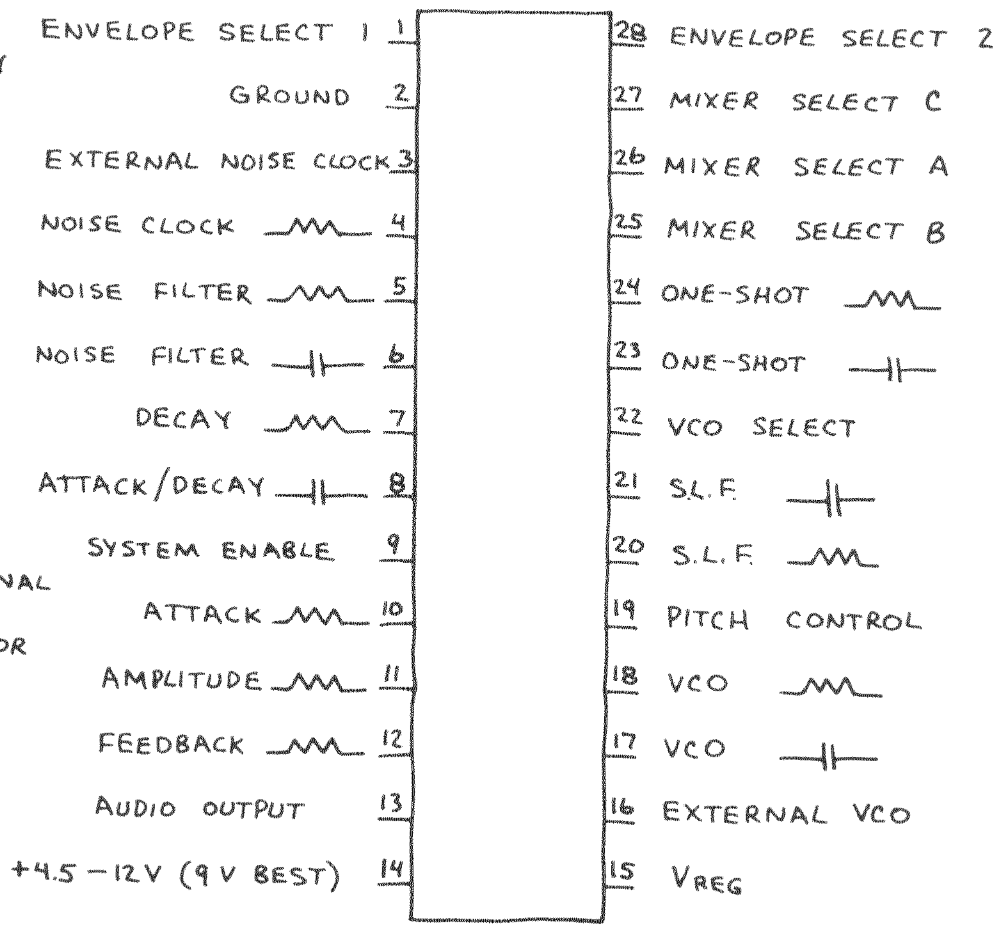


STEAM TRAIN WITH WHISTLE

COMPLEX SOUND GENERATOR
SN76477N

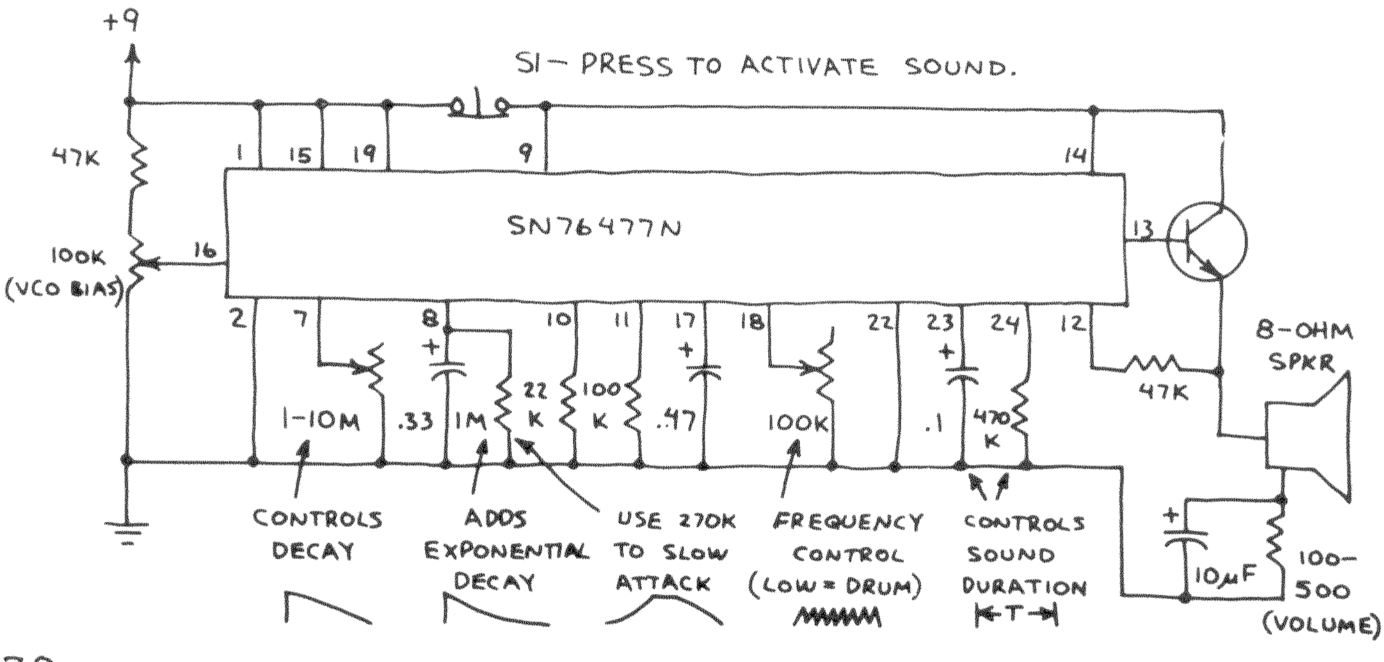
NOTE: THE SN76488 INCLUDES BUILT-IN SPEAKER AMPLIFIER. THE SN76477 DOES NOT.

INCORPORATES S.L.F. (SUPER LOW FREQUENCY OSCILLATOR), VCO (VOLTAGE CONTROLLED OSCILLATOR), NOISE GENERATOR AND A MIXER THAT ALLOWS THE OUTPUTS FROM ONE OR MORE OF THE ABOVE TO BE COMBINED. CAN BE OPERATED TOGETHER WITH APPROPRIATE RESISTORS AND CAPACITORS TO PRODUCE MANY KINDS OF SOUNDS. CAN BE CONTROLLED BY EXTERNAL LOGIC. SEE DATA SUPPLIED WITH CHIP FOR MORE INFO.

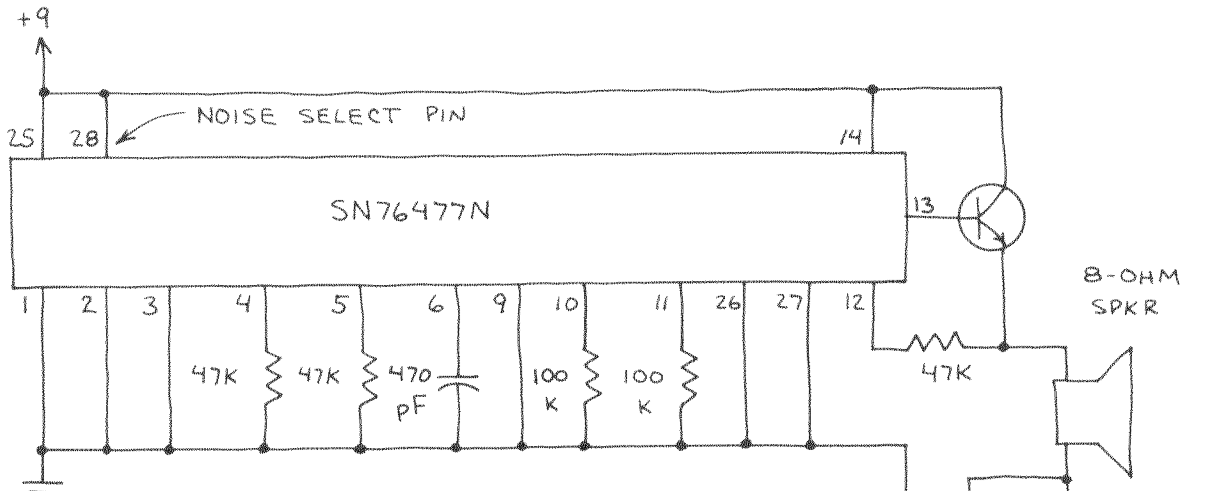


THIS CHIP IS EASY TO USE IF YOU FOLLOW DATA SHEET INSTRUCTIONS.

PERCUSSION SYNTHESIZER

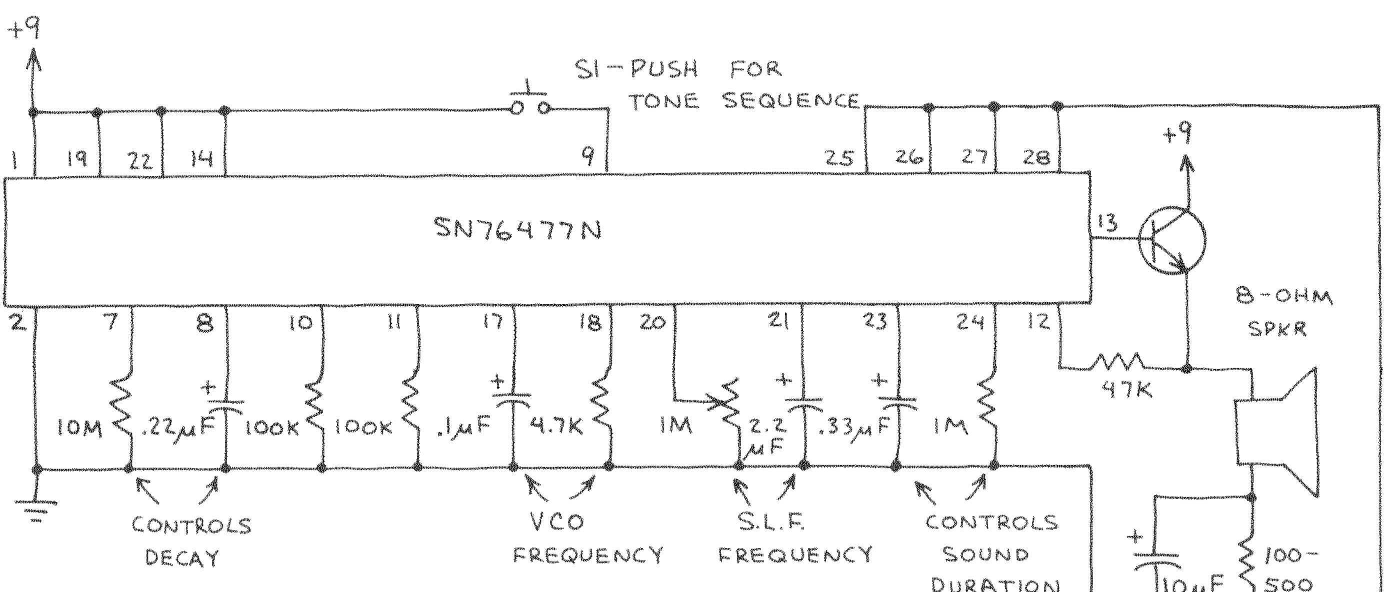


NOISE GENERATOR



PRODUCES STEADY HISS. MAKE SNARE DRUM BY CONNECTING PUSHBUTTON IN SERIES WITH SPEAKER. ADD S.L.F. OSCILLATOR TO MODULATE THE HISS. (SELECT S.L.F. + NOISE BY CONNECTING PINS 25 AND 26 TO GND AND PIN 27 TO +9V. ADD 1M POT FROM PIN 20 TO GND AND 1μF CAPACITOR FROM PIN 21 TO GND.) SOUNDS LIKE STEAM TRAIN OR PROPELLER AIRCRAFT DEPENDING ON ADJUSTMENT OF 1M POT.

UNIVERSAL UP-DOWN TONE GENERATOR



PRESS S1 AND RELEASE TO HEAR UNDULATING TONE THAT GRADUALLY DECAYS AND STOPS. CHANGE VCO AND S.L.F. COMPONENTS FOR MANY DIFFERENT SOUND EFFECTS RANGING FROM SIREN TO SCIENCE FICTION MOVIE SOUNDS. FOR CONTINUOUS SOUND, OMIT COMPONENTS AT PINS 7, 8, 23, 24 AND GROUND PIN 9.

the frequency and reducing the capacitance will raise it.

The entire circuit should be self-contained and complete with battery and miniature acoustic transducer. The LM3909 can even be powered by a single 1.5-volt silver-oxide cell of the type used to power digital watches. This will allow you to assemble a miniature unit. The audio output could be provided by a miniature earphone salvaged from a discarded hearing aid. Alternatively, you can use a midget transistor-radio earphone. ■

14. Steam Engine and Whistle Sound Synthesizer

Originated at Texas Instruments, the circuit is designed around the SN76477 sound-effects chip. In operation, the output of the chip's noise generator is switched on and off by its super-low-frequency (SLF) oscillator. Potentiometer *R2* controls the switching rate, hence the speed of the engine sound.

When *R2*'s resistance is high, the sound resembles that of a stopped train whose engine is idling. As the potentiometer's effective resistance is reduced, the sound speeds up and resembles that produced by an accelerating train.

The sound of the train's whistle is derived from the output of the voltage controlled oscillator (vco) in the SN76477. The values of *C2* and *R3* control the whistle's pitch. Pressing *S1* activates the whistle.

The output of the SN76477 is amplified by *Q1*, which in turn drives a small 8-ohm speaker. Resistor *R11* controls the amplitude of the sound from the speaker. If you prefer, you can drive an external audio power amplifier with the signal voltage appearing between pin 13 of the IC and ground.

For a little more money, you can buy the SN76488. This chip has everything that the SN76477 has, as well as a built-in amplifier, but it has a different pinout. If you use this chip, omit *Q1* from the circuit in Fig. 1 and connect pin 13 directly to one terminal of the speaker. Connect the second speaker terminal to ground through *C4*. Resistors *R10* and *R11* should be omitted.

A drawback of the circuit in Fig. 1 is that the steam-engine sound generator is disabled when the whistle is activated. This problem can be remedied by adding a simple whistle-multiplexer circuit (Fig. 2) and by removing *S1* from the circuit of Fig. 1.

When activated, the whistle multiplexer, which was also suggested by Texas Instruments, switches the whistle on and off at a rate of 26 kHz. Even though the steam-engine sound is turned off when the whistle is on, the switching rate is far too fast for the ear to detect. Consequently, the whistle seems to be superimposed on the sound of the engine. The only audible effect of the whistle multiplexer on the steam-engine sound is a slight reduction in volume when the whistle is activated.

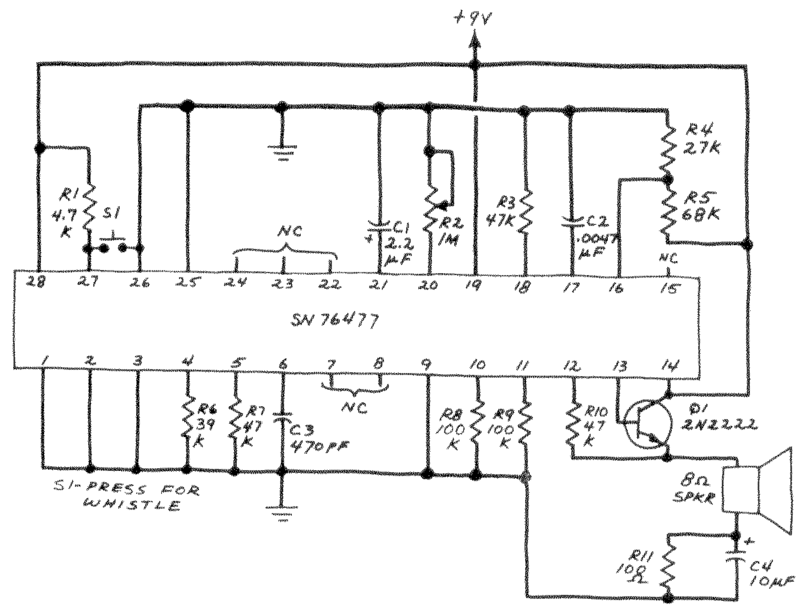


Fig. 1. Schematic using the SN76477 sound-effects chip to generate sounds of a steam locomotive.

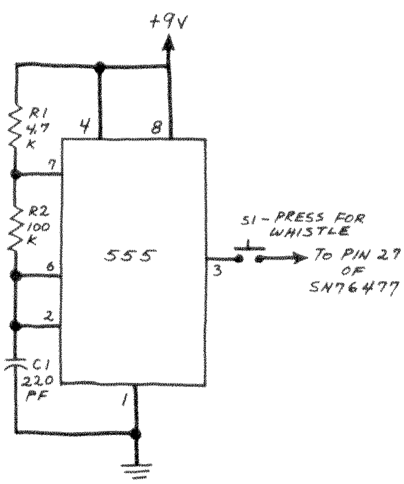


Fig. 2. Whistle multiplexer for steam-engine simulator.

Model railroaders might want to modify this circuit so that the engine sound speeds up *automatically* when a model train is accelerating. This can be done with the help of a homemade optoisolator made from a small lamp and a cadmium-sulfide photocell. Use black electrical tape or heat-shrinkable tubing to mount the lamp adjacent to the photocell and to block ambient light.

Connect the lamp in the optoisolator to the train's transformer. Remove *R2* from the circuit of Fig. 1 and connect the photocell in its place. As the train's speed is increased, the lamp will glow more brightly. This will reduce the resistance of the photocell and increase the rate at which the sound-effects generator is switched on and off by the SLF oscillator.

It might be necessary to add a series resistor between the photocell and the circuit to match the sound of the engine with the speed of the train. You can achieve the same result by blacking out part of the photocell's window. ■