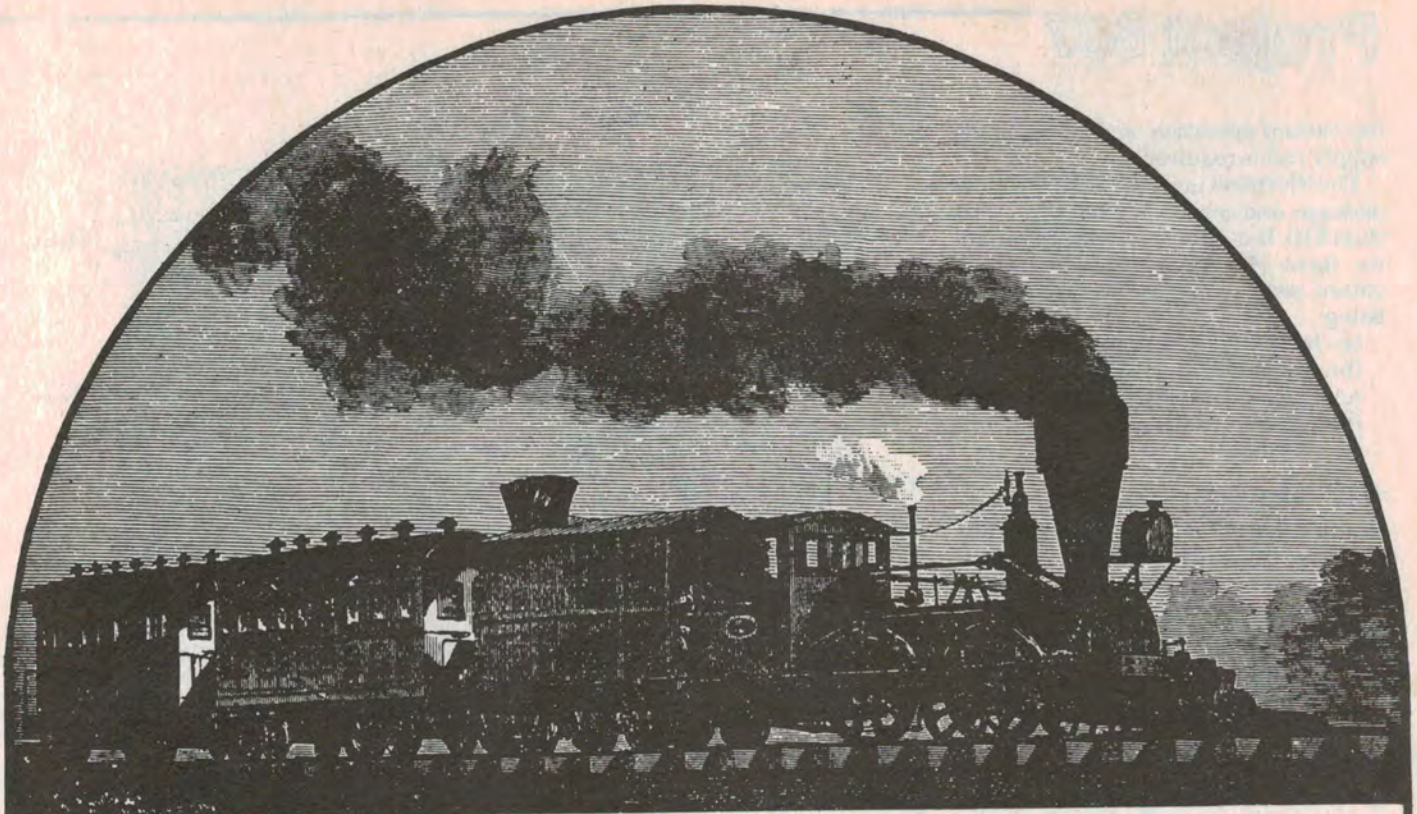


Simple sound effects

Part 1

Phil Wait

One of the attractions of the more sophisticated video games seen in 'fun' arcades these days is the realistic array of sound effects that go with the action — gunshots, bomb whistles and explosions, etc. This simple group of projects employs just one IC that does all the hard work.

THOSE 'CANNON SHOTS' and explosions that go with the popular 'Space Invaders' video games and its variants add a measure of interest, feedback and stimulation to the action in which you participate on screen. Those sounds are electronically synthesised — that is, they consist of a complex mixture of waveforms that make up the required sound.

A 'bomb drop and explosion' is a remarkably complex sound when analysed carefully. Looking at it simply, there is a descending tone followed by a burst of noise that dies away in intensity. The descending tone starts at quite a high pitch and is not a 'pure' tone (i.e: a sine wave). The explosion is a burst of noise that commences suddenly and dies away slowly in a recognisable way (usually exponentially). While it is possible to electronically produce very nearly an exact replica of a bomb drop and explosion, some compromises are acceptable to reduce the complexity and cost of the task and yet produce a recognisable replica of the sound.

To produce such sound using conventional components — transistors, diodes, op-amps, resistors and capacitors — would require a whole legion of components. Fortunately, the IC manufacturers can come to our rescue here and much of the circuitry can be incorporated into a complex integrated circuit requiring the addition of a minimum of external components and the appropriate interconnections to synthesise the required sound. Generating a wide variety of sounds fortunately requires only a limited number of functional blocks, such as: a noise generator, voltage-controlled oscillators, multivibrators, envelope generators (a sort of modulator), mixers and amplifiers.

Texas Instruments, the giant US-based component and equipment manufacturer, have designed a series of complex function ICs for various applications and amongst them is the SN76488 Complex Sound Generator. This chip contains both linear and digital circuitry and is intended for use in applications requiring audio feedback to the user — video games, pinball, alarms, toys, etc, or industrial indicators, feedback controls and the like. Power consumption is quite low, allow-▶

ing battery operation, and only a single supply rail is required.

The SN76488 is contained in a 28-pin package and can be purchased for less than $10. It is quite a versatile chip, but we have chosen to describe how to obtain only five sounds effects, these being:

(a) bomb drop and explosion
(b) steam train and whistle
(c) alarm ('phasor')
(d) phasor and explosion
(e) gunshot

The first three are described this month, the last two will follow next issue. Only one pc board is required for all five projects. Before going on to the general construction details, let us take a look at what's inside the SN76488 and what each function block does. Not every function block inside the IC is used to produce each sound, so it is necessary to learn what each does before you can understand how individual sounds are produced or how you can use the chip to synthesise sounds for your own requirements.

Inside the SN76488

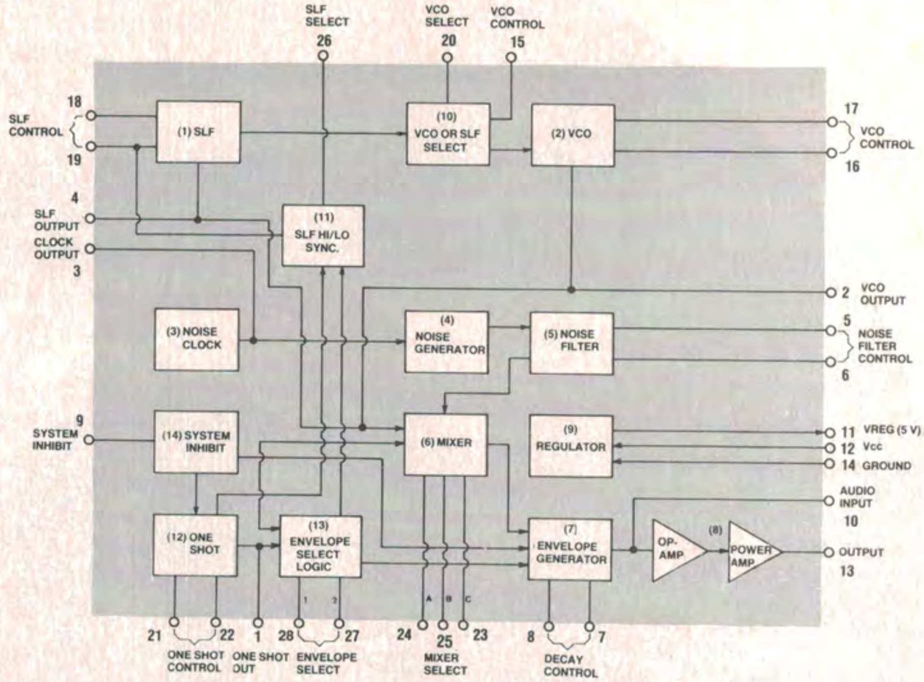
There are 14 functional circuit blocks contained within the IC.

(1) super low frequency oscillator (SLF)
(2) voltage-controlled oscillator (VCO)
(3) noise clock
(4) noise generator
(5) noise filter
(6) mixer
(7) envelope generator
(8) op-amp and power amp
(9) regulator
(10) VCO/SLF select
(11) SLF hi/lo synchroniser
(12) one shot
(13) envelope select
(14) system inhibit

Note that blocks one to four can be considered the basic *sound generators*, blocks five, six and seven are *sound modifiers*, while block eight provides the *output* and block nine distributes the power supply. Blocks 10 to 14 *control* the other functions.

(1) The SLF

This is an oscillator that can operate over the range from 0.1 Hz (one cycle every ten seconds) to 20 kHz, but it is not normally used at frequencies above about 30 Hz. The frequency of oscillation is determined by a resistor and capacitor, the resistor from pin 18 to 0 V, the capacitor from pin 19 to 0 V.



Internal block diagram of the SN76488.

The required frequency can be determined from the following formula:

$$SLF\ (Hz) = \frac{0.66}{(9000 + R_s)\, C_s}$$

where: R_s is resistor on pin 18
C_s is capacitor on pin 19

The SLF produces a square wave with a 50% duty cycle (high and low for equal periods) and a triangular wave. The square wave is internally connected to the mixer (6) and is available as an output on pin 4. The triangular wave goes to the VCO/SLF select block (10).

(2) The VCO

This is an oscillator which can be swept over a 10:1 frequency range by either the SLF output or an externally applied voltage (via pin 15 and the VCO/SLF select). Control of the VCO via the VCO/SLF select is discussed in (10).

The VCO can also be controlled by varying the voltage on pin 19 (SLF control, capacitor pin). The minimum frequency of the VCO is set by a resistor between pin 17 and 0 V and a capacitor between pin 16 and 0 V. The maximum frequency will always be 10 times the minimum frequency. The required minimum frequency can be derived from the following equation:

$$VCO_{min.}\ (Hz) = \frac{0.6}{(9000 + R_l)\, C_l}$$

where: R_l is resistor on pin 17
C_l is capacitor on pin 16

The output from the VCO is a square wave, available on pin 2. Internally, the VCO output is applied to one input of the mixer (6).

(3) Noise clock

This is an oscillator that feeds timing pulses to the noise generator (4), which generates pseudo-random noise digitally. The noise clock operates at a frequency of about 10 kHz and its output is available on pin 3. This output can be used for multiplexing.

(4) Noise generator

This is a digital circuit that produces pseudo-random white noise. The output is not directly available on one of the IC pins, being passed internally to the noise filter.

(5) Noise filter

This is a variable bandwidth low pass filter. The filter cutoff point is determined by an RC network consisting of a resistor between pin 5 and 0 V, and a capacitor between pin 6 and 0 V. The cutoff frequency is determined by:

$$F_c\ (Hz) = \frac{0.43}{(9000 + R_c)\, C_c}$$

where: R_c is the resistor on pin 5
C_c is the capacitor on pin 6

The output of the noise filter feeds an input to the mixer (6).

(6) Mixer

The mixer selects one or a combination of the inputs from the VCO, SLF or noise generator (via the filter), its output passing directly to the envelope generator. The mixer has three 'select' terminals, pins 23, 24 and 25, permitting eight output combinations according to Table 1. A 'low' (L) or a 'high' (H) on the appropriate pins

Mixer Select Inputs			Mixer
C (Pin 23)	B (Pin 25)	A (Pin 24)	Output
L	L	L	VCO
H	L	L	SLF
L	H	L	NOISE
H	H	L	VCO/NOISE
L	L	H	SLF/NOISE
H	L	H	SLF/VCO/NOISE
L	H	H	SLF/VCO
H	H	H	INHIBIT

Table 1. Mixer Select logic.

Envelope Select 1	Envelope Select 2	Selected Function
Pin 28	Pin 27	
L	L	VCO
L	H	Mixer Only
H	L	One-Shot
H	H	VCO with AC

Table 2. Envelope Select logic.

activates the selection. A low is 0 V, a high is +5 V.

The mixer performs as an AND gate, actually. To obtain two sounds simultaneously, multiplexing is required. This is accomplished by switching the mixer select lines at a sufficiently rapid rate that the two sounds seem to occur simultaneously. To prevent interaction with the sound output, the multiplexing rate is usually set above the human hearing frequency range. To provide equal amplitudes for both sounds the multiplexing drive signal must have a 1:1 duty cycle.

(7) Envelope generator

This block modulates the mixer output to give the sound the required 'decay' characteristics. The sound from the mixer can be made to die away (decay); the length of time it takes to do so is determined by an RC network connected to the 'decay control' pins — a resistor between pin 7 and 0 V and a capacitor between pin 8 and 0 V.

The decay is actually a ramp at the end of the sound. The approximate time it takes to ramp the sound amplitude to zero may be derived from:

$$\text{Decay (seconds)} = 1.5(9000 + R_d)C_d$$

where: R_d is resistor on pin 7.
C_d is capacitor on pin 8.

The decay has no effect on the mixer-only function, but for the one shot, the VCO, and the VCO with alternating cycle envelopes, the decay ramp is triggered by each high-to-low transition of the envelope and prolongs the sound at a decaying volume.

(8) Op-amp and power amp

This provides the audio output. The op-amp brings the level out of the envelope generator up to that required by the power output stage, the latter providing 125 milliwatts maximum to an eight ohm speaker. A higher impedance speaker can be used, with reduced output power, but a four ohm speaker is not suitable.

The input to the op-amp is accessible on pin 10 and an externally produced audio signal may be mixed in at this point. Coupling to this input should be via a capacitor.

(9) The regulator

An internal 5 V regulator is provided and it can operate from a supply rail of between 7.5 and 10 volts, connected with the positive to pin 12, negative (0 V) to pin 14. This conveniently permits operation of the SN76488 chip from a 9 V battery. The 5 V regulator output is accessible on pin 11 and can supply up to 5 mA current.

(10) VCO/SLF select

The VCO can be swept by the SLF or an external signal applied to pin 15 (VCO control). Pin 20 controls the operation of this logic block, which is in effect a switch. A high on pin 20 permits the VCO to be controlled by the SLF, a low permits the VCO to be controlled by the external voltage or signal, applied to pin 15.

The frequency of the VCO is inversely proportional to the voltage on pin 15. The higher the voltage, the lower the VCO frequency. Voltages above 2.35 V applied to pin 15 will produce an inaudible frequency from the VCO's output.

(11) SLF hi/lo synchroniser

This block permits control of the SLF by the one shot (12) and the envelope select (13). The SLF can be inhibited at any time by applying a logic low to pin 26.

(12) One shot

A high-to-low transition on pin 9 triggers 'one shot' sounds such as a gunshot or explosion. The maximum duration of a one shot sound is about 10 seconds and is determined by an RC network; a capacitor between pin 21 and 0 V and a resistor between pin 22 and 0 V. The duration can be determined from the formula:

$$\text{Duration (seconds)} = 0.91\,(R_d + 9000)\,C_d$$

where: R_d is the resistor on pin 22
C_d is the capacitor on pin 21.

If the one shot is terminated early by taking the system inhibit high, the one shot timing must be allowed to end so that an internal latch will be reset before another one shot can be triggered. The one shot may also be controlled by external logic eliminating the need for the one shot resistor and capacitor. This is done by triggering the one shot in the normal way with the system inhibit input, and terminating it by taking pin 21 (one shot capacitor) high.

The output of the one shot is fed through the envelope select logic to the envelope generator, and is therefore operable only when the one shot envelope is selected by the envelope select inputs. The one shot does not generate sound as such, but provides an envelope for the sound supplied to the envelope generator by the mixer.

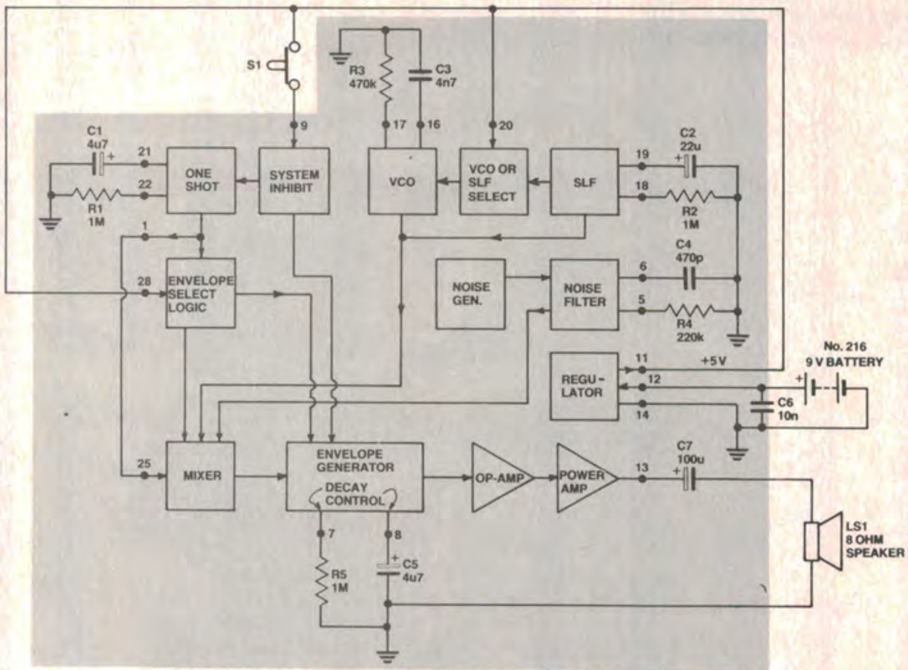
A one shot output pulse is available at pin 1. In the one shot mode, the SLF ramp can be started either high or low by placing a high or low on the SLF Sync Select, pin 26.

(13) Envelope select

This block determines how the envelope of sound is formed, whether directly from the signals applied to the mixer or from the one shot. Pins 27 and 28 control the operation of this block, and a combination of highs and lows determines which function is selected according to Table 2. The VCO output to the mixer can be selected (SLF inhibited), mixer only output (one shot inhibited), one shot and VCO plus other (ac) signals.

(14) System inhibit

The system inhibit logic provides inhibit/select control for the sound output of the system: a high logic level at the system inhibit terminal (pin 9) inhibits the sound output, a low logic level (or open) enables it. This input also triggers the one shot circuit for momentary sounds such as gunshots, bells, or explosions. The one shot logic is triggered on the negative-going edge of the system inhibit input. This may be accomplished by means of a momentary switch or by a square wave input to system inhibit. The system inhibit input must be held low for the entire duration of the one shot sound, including attack and decay periods if the sound is to be completed. Taking the system inhibit input high early terminates the sound. Note that the one shot is operable only when the proper envelope select logic is selected. ▶



Circuit for the ETI-607A Bomb Drop & Explosion. The pushbutton is held down for the duration of the event. Release it and press again to repeat.

HOW IT WORKS — ETI 607A BOMB DROP AND EXPLOSION

This unit employs most of the function block in the SN76488. The SLF provides a linearly increasing voltage waveform, or ramp, to the VCO, taking several seconds for the ramp voltage to rise from zero to maximum value. This causes the VCO to produce a tone which 'glides' down in pitch, making the 'bomb drop' effect. The explosion is generated by the Noise Generator/Filter and the Envelope Generator. It starts with a burst of noise, which dies away in intensity exponentially in a few seconds.

The whole sequence is triggered by operating the pushbutton, S1. This applies a high (+5 V) to the input of the System Inhibit block, pin 9. This in turn triggers the One Shot and the Envelope Generator. At the commencement of the One Shot timing period, the One Shot triggers the SLF HI/LO Sync. (see SN76488 block diagram), starting the SLF, and the VCO does its thing. At the end of the One Shot timing period the Envelope Select Logic becomes operative, the SLF is disabled and the Envelope Generator commences to do *its* thing. The Mixer selects the VCO output at the start of the One Shot timing period and the Noise Generator/Filter output at the end of the One Shot timing period. Thus the two sounds are switched through to the audio output stage in sequence, the Envelope Generator modifying the noise so that it dies away, the time it takes to do so being controlled by the time constant of R5, C5.

The starting pitch of the VCO is determined by R3 and C3, the rate of rise of the voltage ramp produced by the SLF is determined by C2 and R2, while the One Shot timing period is determined by the time constant of C1 and R1. The frequency characteristics of the broadband noise produced by the Noise Generator are modified by R4 and C4 connected to the noise filter control pins (5 and 6).

Audio output is coupled to the loudspeaker via C7, a 100u electrolytic capacitor.

General construction

All the projects described use the one pc board design. As the SN76488 is available in two packages of different sizes and pin spacings — the A package, a conventional 28-pin package with 15.24 mm spacing between the pin rows and 2.54 mm pin spacing, and the smaller NF package having 10.16 mm spacing between the pin rows and 1.52 mm pin spacing — we have had to provide two pc board designs to accommodate the different packages. Each board is marked accordingly. Make sure you purchase the correct board to suit the device package you have. All the component pads and holes are in exactly the same position on each board and the overlay diagrams given in these articles apply to either board.

The SN76488 dominates the pc board. Only the required components are assembled into the board according to each overlay diagram to obtain the required sound generator. Naturally enough, the polarity of the IC should be noted as well as the polarity of electrolytic and tantalum capacitors used. Commence construction by assembling the passive components, followed by the IC. This is not a CMOS device and no special care is required, apart from being careful not to bend any pins under the device when inserting it. If you wish, a socket may be used for the IC. This way, you can assemble the five projects and purchase only one IC, swapping between the boards as you need to use them!

Wiring to the switches, the speaker and the supply should be attached last.

The unit may be mounted in any convenient-sized box and the speaker mounted on the front. Alternatively, it may be wired into an existing piece of equipment. We'll have to leave these arrangements up to you.

PARTS LIST — ETI 607A BOMB DROP + EXPLOSION

Resistors all ½W, 5%

R1, R2, R5	1M
R3	470k
R4	220k

Capacitors

C1, C5	4u7/16 V electro.
C2	22u/16 V tant. or RBLL
C3	4n7 greencap
C4	470p ceramic
C6	10n greencap
C7	100u/16 V electro.

Semiconductors

IC1	SN76488

Miscellaneous

S1	SPST push-to-make pushbutton switch

ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip.

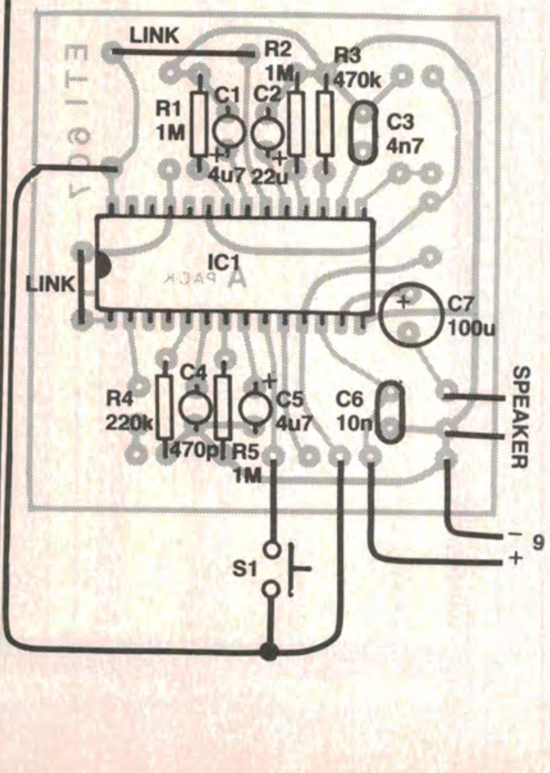
Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$16 - $19

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

Component overlay for the ETI-607A Bomb Drop & Explosion.



PARTS LIST — ETI 607B STEAM ENGINE + WHISTLE

Resistors	all ½W, 5%
R1	330k
R2	470k
R3	56k
R4	100k
R5	1k
Capacitors	
C1	1u/16 V tant. or RBLL
C2, C3	470p ceramic
C4	10n greencap
C5	100u/16 V electro.
Semiconductors	
IC1	SN76488
Miscellaneous	
S1	SPST push-to-make pushbutton switch;

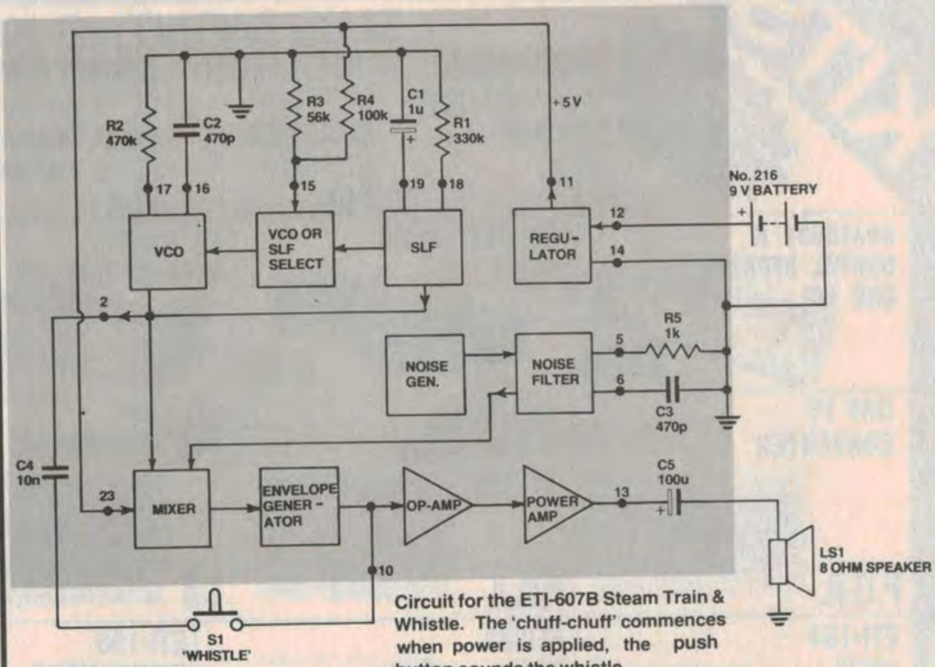
ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$14 - $17

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



Circuit for the ETI-607B Steam Train & Whistle. The 'chuff-chuff' commences when power is applied, the push button sounds the whistle.

HOW IT WORKS — ETI 607B — STEAM TRAIN AND WHISTLE

In this unit the Noise Generator/Filter is employed to produce the basic 'steam engine' sound, this being modulated by the SLF to produce the 'chuff-chuff' so characteristic of steam locomotives. The whistle is produced by the VCO, which is set to a particular non-varying pitch, and the output is switched into the audio input pin to produce the whistle.

The broadband noise from the Noise Generator is modified by the Noise Filter, the frequency characteristics being determined by R5 and C3 connected to the Noise Filter Control pins (5 and 6). The Noise Filter Output is fed via the Mixer and the Envelope Generator (which doesn't function here) to the audio output stages. The SLF square wave output effectively modulates the noise to produce a noise burst followed by a silent period, then another noise burst. Thus the chuff-chuff sound is produced. This sound is continuous whilst power is applied to the unit.

A resistive divider, R3/R4, provides about 1.8 volts at the VCO programming input, pin 15. This sets the VCO frequency to a convenient pitch within its range, providing a suitable pitch for the whistle. The VCO output is coupled to the audio input (pin 10) via C4 and the pushbutton, S1. When S1 is pressed, the whistle is heard over the chuff-chuff sound.

The SLF frequency is determined by C1 and R1, while the combination of R2/C2 and the voltage on pin 15 determines the VCO frequency. Output to the loudspeaker is coupled via C5, a 100u electrolytic capacitor.

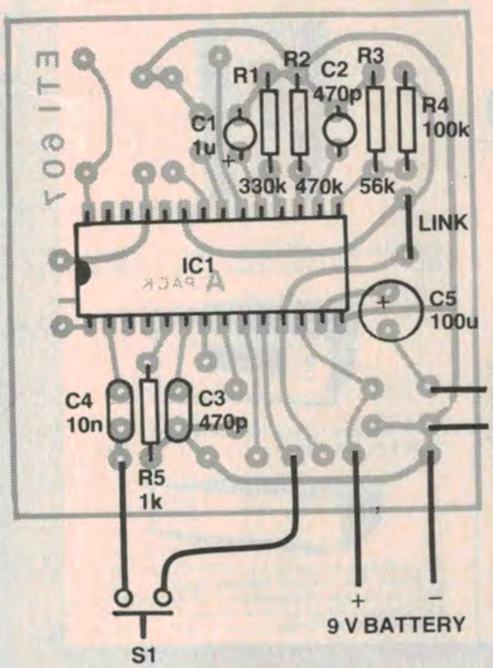
ETI-607A

This produces a 'bomb drop and explosion' sound at the press of a button. Alternatively, the pushbutton, S1, could be replaced by a pair of relay contacts operated by a piece of equipment or a transistor (emitter to pin 9, collector to other side of S1) that is turned on by a logic high applied to its base via a resistor.

This project is one of the most complex, using almost every functional block within the SN76488. Varying R3 and C3 a little will vary the pitch range of the 'bomb drop' (descending whistle), while varying R4 or C4 a little will vary the characteristics of the explosion. Note that it is generally easier to 'fine tune' things by varying the resistor values. The duration of the event can be varied by varying the value of either C1 or R1 and the decay of the explosion can be changed by varying R5 (varying C5 produces quite gross changes in the decay period).

Watch that you insert the link on the pc board in this one, located at the 'notch' end of the IC.

Component overlay for the ETI-607B Steam Train and Whistle.

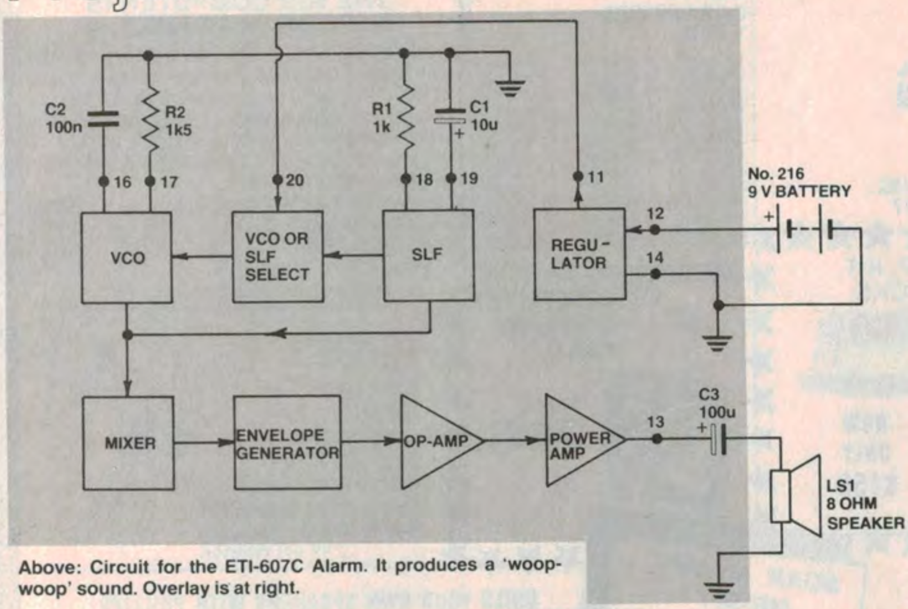


ETI-607B

Aahh, the nostalgia! Clive Robertson (*), this is for you — a steam train (chuff-chuff) and whistle. For that *authentic* touch, deft constructors can fashion a cow-catcher out of tinned copper wire to attach to the unit!

The chuff-chuff runs continuously once power is applied and the whistle sounds when the pushbutton is pressed. The VCO is used to provide the whistle while the SLF modulates the noise generator/filter output to produce the steam train's chuff-chuff sound. The chuff-chuff rate may be varied by changing the values of R1 and C1, while the chuff-chuff sound may be varied by altering the values of R5 and C3. The pitch of the whistle may be varied by changing the values of R2 and C2. For a special effect, you can control the chuff-chuff rate manually by replacing R1 with a 1M potentiometer. ▶

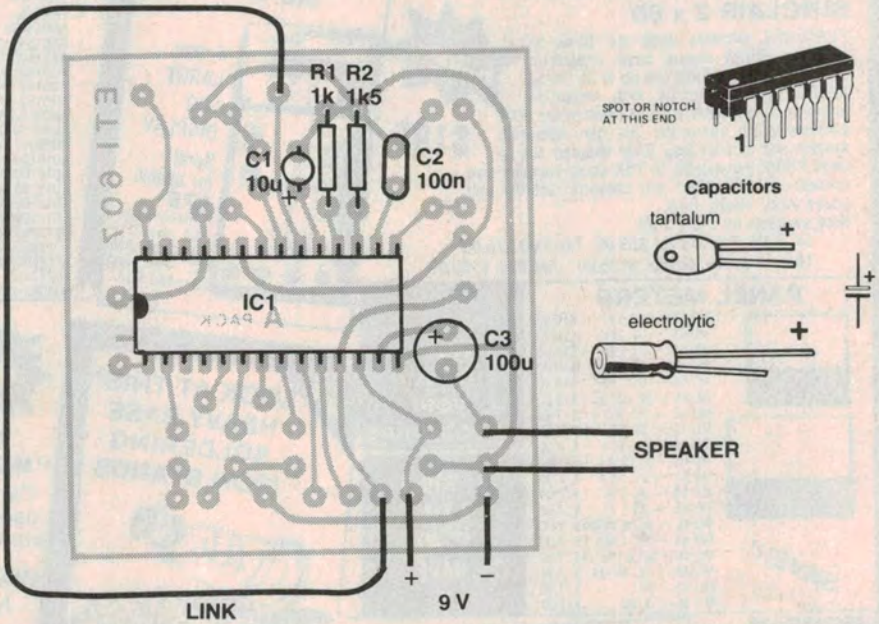
**(In)famous breakfast announcer on ABC second network station 2BL in Sydney.*



Above: Circuit for the ETI-607C Alarm. It produces a 'woop-woop' sound. Overlay is at right.

ETI-607C

The Texas Instruments' application notes include a 'phasor' circuit that produces a sound rather like a 'woop-woop' alarm. It's about the simplest project of the lot! The SLF is simply employed to sweep the VCO over a convenient range at a suitable speed. Turning the power supply on and off by inserting a switch or relay contacts in series with either the positive or negative battery leads serves to trigger the alarm. The VCO pitch may be varied to suit your requirements by changing the values of either C2 or R2, while the rate at which the VCO is swept may be varied by altering the value of either R1 or C1. ●



HOW IT WORKS — ETI 607C ALARM ('PHASOR')

This produces an alarm sound that's a real attention-getter! Operation is simplicity itself. The SLF is set to operate at a few cycles per second, determined by R1/C1. The ramp output of the SLF is selected to sweep the VCO by applying a high (+5 V) to the control input of the VCO/SLF Select block (pin 20). The VCO is thus swept across its range several times per second. Maximum frequency of the VCO is determined by R2/C2. Output from the VCO is coupled to the audio output stages via the Mixer and Envelope Generator (inoperative here). The speaker is connected via the obligatory 100u electrolytic capacitor, C3.

PARTS LIST — ETI 607C

Resistors all ½W, 5%
- R1 .... 1k
- R2 .... 1k5

Capacitors
- C1 .... 10u/16 V electro.
- C2 .... 100n greencap
- C3 .... 100u/16 V electro.

Semiconductors
- IC1 .... SN76488

Miscellaneous
ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip; switch (if needed).

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$14 - $17

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

This photograph shows the Steam Train & Whistle built up. We leave the housing to you as individual requirements will vary.