20 SOUND GENERATOR AND ALARM PROJECTS

Operational amplifiers can be used in a variety of sound generator and audible-alarm applications. They can readily be adapted for use as code-practice oscillators, door signalling systems, simple musical instruments, metronomes, audible water alarms, light or heat-activated alarms, and as contact-operated audible alarms, etc. In such applications the op-amps can be used to give output powers of a few milliwatts directly, or of several watts with the aid of additional power-booster circuitry.

Twenty useful op-amp sound generator and audible-alarm projects of various types are described in the present chapter. All of these projects are designed around the popular type 741 integrated-circuit op-amp, and the pin connections shown in the following diagrams apply to the 8-pin dual-in-line version of the device only.

Basic relaxation oscillator circuits

Figure 5.1a shows the basic circuit of a simple relaxation oscillator or square-wave generator of the type described in Chapter 4. The op-amp in this circuit is used as a combined voltage comparator and regenerative switch, and the circuit action is as follows.

Suppose initially that the op-amp has just regenerated into positive saturation. Under this condition half of the saturation voltage is switched to the positive terminal via potential divider $R_2 - R_3$, and a rising exponential voltage is switched to the negative terminal via the $R_1 - C_1$ time-constant network. Since the positive terminal is positive relative to the negative terminal at this moment, the op-amp is held in positive saturation. As time passes C_1 charges up via R_1, and the voltage at the negative terminal rises exponentially towards the saturation level. Eventually, a point is reached at which the negative terminal voltage becomes slightly more positive than that on the positive terminal, and the op-amp comes out of saturation. As the op-amp starts to come out of positive saturation a regenerative action is initiated, and the op-amp switches abruptly into negative saturation.

When regeneration is complete half of the negative saturation voltage is applied to the positive terminal via $R_2 - R_3$, and a negative rising exponential voltage is applied to the negative terminal via $R_1 - C_1$. The terminal polarities ensure that the op-amp is held in negative saturation at this time. As time passes the negative terminal becomes progressively

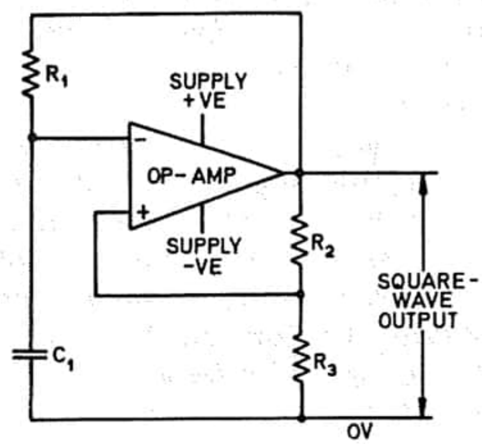


Figure 5.1a. Basic relaxation oscillator circuit.

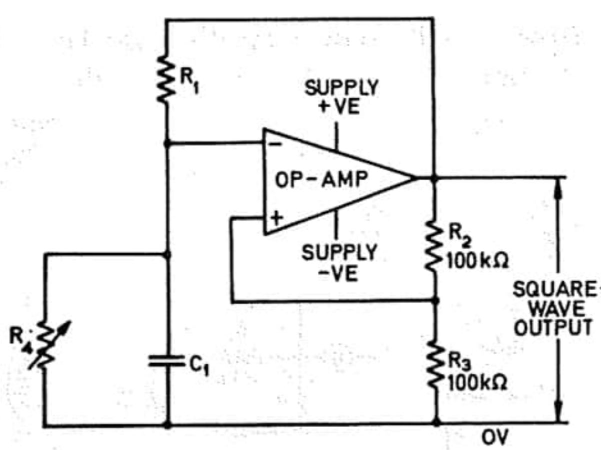


Figure 5.1b. Basic resistance-activated relaxation oscillator circuit.

more negative, and eventually becomes slightly more negative than the positive terminal. At this point a regenerative action is again initiated, and the op-amp switches back into positive saturation. The sequence then repeats ad infinitum.

Thus, the *Figure 5.1a* circuit generates a square wave output, and has its frequency controlled by $R_1 - R_2 - R_3$ and C_1. Note that the frequency can be altered by changing any one of these component values, and that oscillation will cease if R_1 is removed from the circuit. Also note from the description of circuit operation above that the op-amp actually changes state in each half-cycle at the point at which the voltage on the negative terminal just exceeds the voltage on the positive terminal. It follows, therefore, that if the negative terminal is prevented from rising to the positive terminal potential, the circuit will cease to oscillate. This simple fact is utilised in the resistance-activated relaxation oscillator circuit of *Figure 5.1b*.

The *Figure 5.1b* circuit is identical to that of *Figure 5.1a*, except that variable resistor R_4 is wired in parallel with C_1 and in series with R_1: the $R_1 - R_4$ combination thus acts as a potential divider that limits the maximum voltage to which the negative terminal can rise. Consequently, if the R_4 value is lower than that of R_1, the negative terminal voltage will be unable to exceed the positive terminal voltage, and the circuit will fail to oscillate. If the R_4 value is greater than that of R_1, on the other hand, the circuit will be able to oscillate. In practice, R_4 resistance changes of only one percent or so are sufficient to initiate or inhibit oscillatory action in the circuit. If R_4 is replaced with a thermistor or a light-independent resistor, therefore, the circuit can be made to function as a very sensitive heat or light-activated alarm. Several practical circuits of this type are described later in this chapter.

Code-practice oscillators

Figure 5.2a shows how the basic relaxation oscillator can be adapted for use as a simple morse code-practice oscillator: the code-practice key

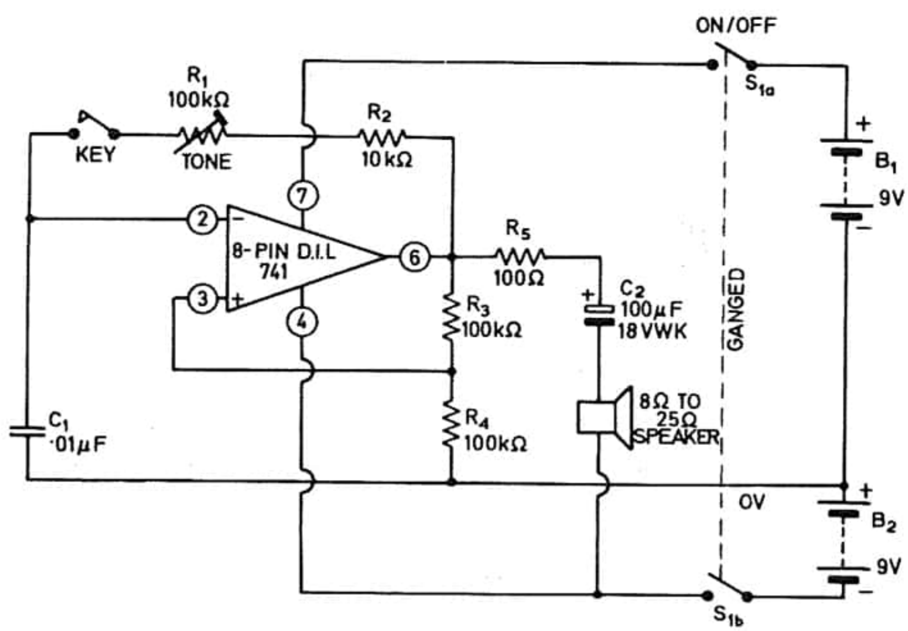


Figure 5.2a. Simple code-practice oscillator.

is wired in series with R_1, so oscillation occurs only when the key is depressed. R_1 is a variable resistor, and enables the practice tone to be varied over the approximate range 400 Hz to 4.4 kHz, to suit individual tastes. The output of the op-amp is fed to a small 8 Ω to 25 Ω speaker via R_5 and C_2. Output powers of only a few milliwatts are generated in the speaker, but this level is more than adequate for this particular application.

The *Figure 5.2a* circuit requires the use of two supply sources. *Figure 5.2b* shows the modifications needed for operation from a single supply source. R_6 and R_7 act as a simple potential divider that enables the positive and negative supply voltages of the op-amp to be derived from a single supply battery, which can be any convenient type that gives a voltage in the range 9 V to 18 V.

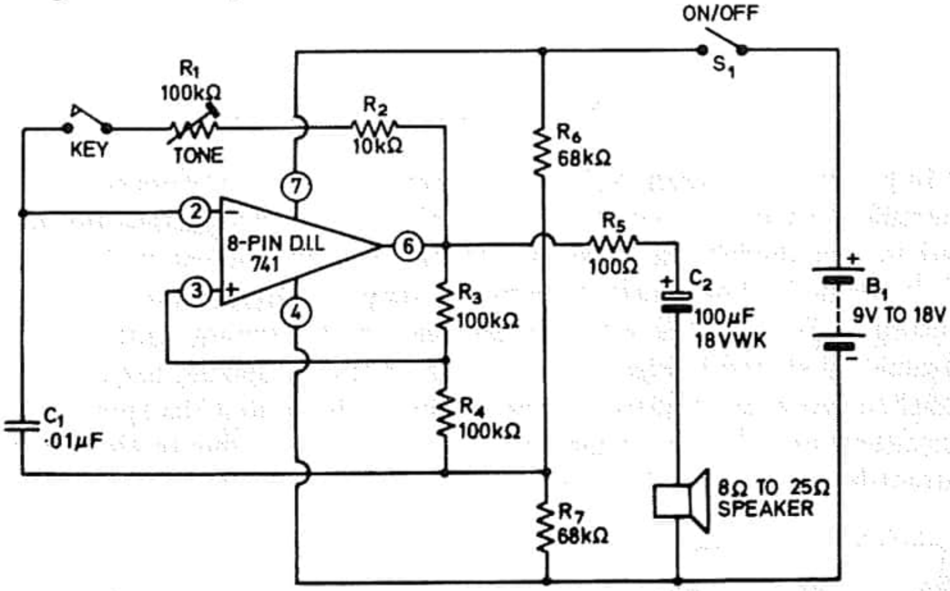


Figure 5.2b. Single supply code-practice oscillator.

Door-signalling systems

Figure 5.3 shows how the basic relaxation oscillator can be adapted for use in a simple door-signalling system. In this case the circuit is provided with three tone-controlling timing resistors, which can be selected via push-button switches S_1 to S_3. With the component values shown a tone of roughly 200 Hz is produced via S_1, 440 Hz is generated via S_2, and 900 Hz is generated via S_3. Note that these tone frequencies rise in steps of roughly one octave, so each push-button switch generates a very distinctive tone. Thus, if S_1 is placed at, say, the front door of the house, S_2 is placed at the side door, and S_3 is placed at the back door, the position of any caller will be readily apparent from the tone of the call signal.

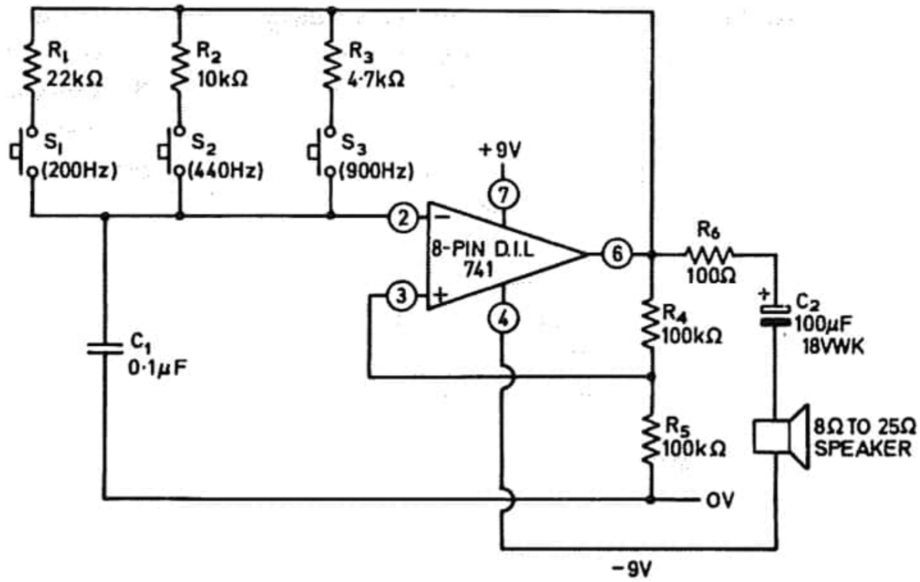


Figure 5.3. Simple door-signalling system.

In practice the *Figure 5.3* circuit generates output powers of only a few milliwatts in the speaker system, and in some applications this low level may be inadequate. In such cases the output level can be boosted to a few hundred milliwatts by wiring a simple complementary emitter-follower buffer stage between the speaker and the op-amp output terminal, as shown in *Figure 5.4*. In this circuit C_3 and R_6 are used as a Zobel network, and enhance circuit stability. Note that the speaker in this circuit must have an impedance of at least 25 Ω, due to the limited current-handling capabilities of output transistors Q_1 and Q_2.

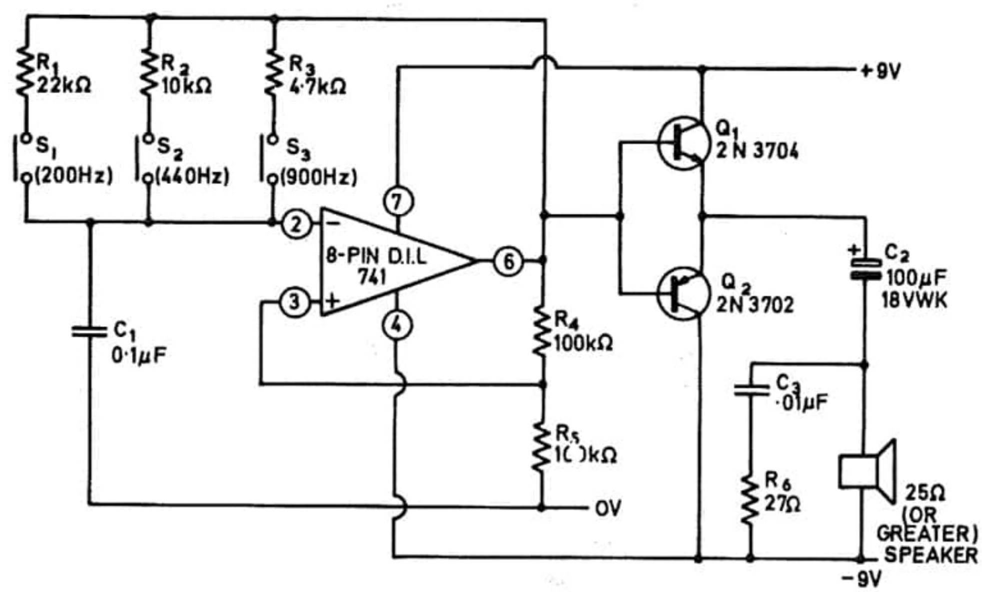


Figure 5.4. Higher-power door-signalling system.

Musical instrument circuits

Figure 5.5 shows how the basic relaxation oscillator can be adapted for use as the basis of a simple keyboard musical instrument. In this case the tone-controlling resistor network consists of a chain of twenty-five resistors wired in series. The junction of each pair of resistors in the chain is taken to a copper or similar low-resistance keyboard strip, and any one of these strips can be connected to the op-amp output via a flying probe. Thus, different tones can be selected by touching the probe onto different keyboard strips, and the circuit functions as a musical instrument that is played via the touch probe.

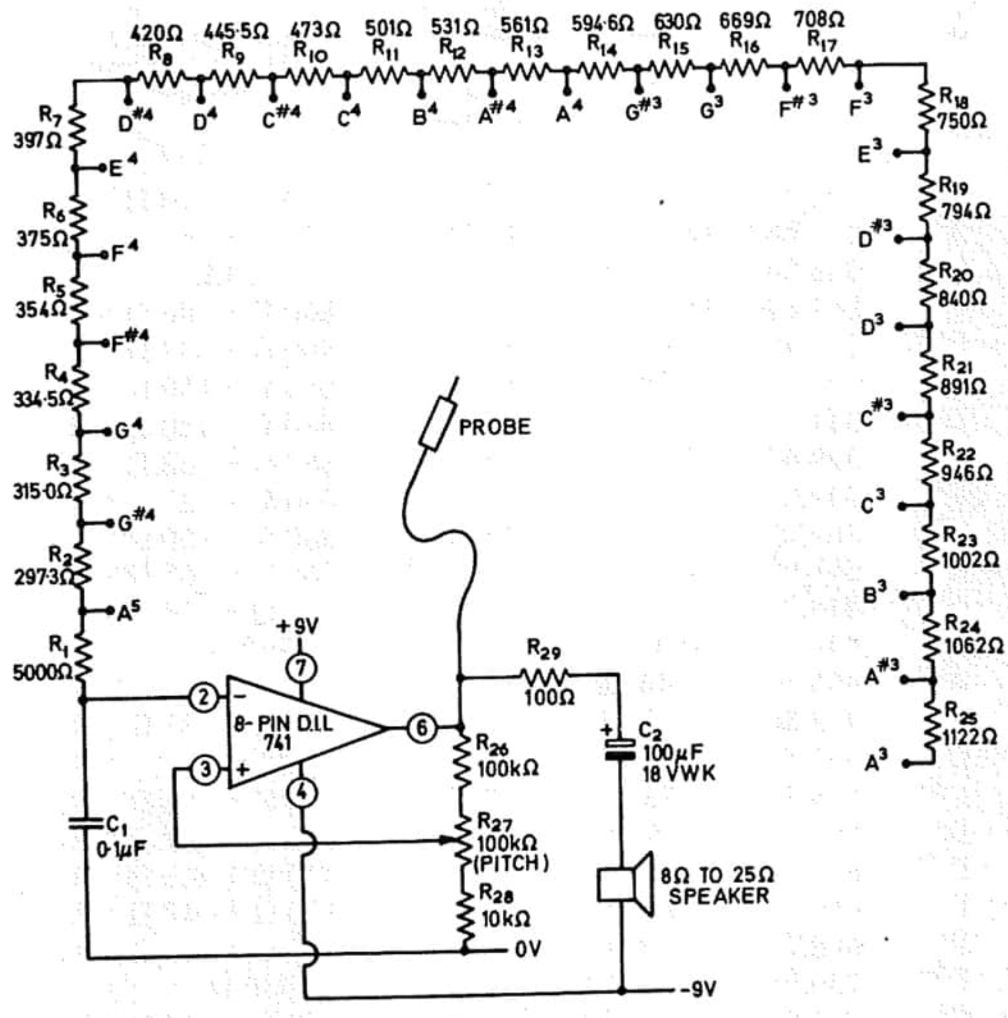


Figure 5.5. A simple keyboard musical instrument.

In practice this simple musical instrument gives 25 notes, and covers two full octaves, from concert pitch A^3 (220 Hz) to A^5 (880 Hz). An adjustable pitch control is included in the circuit, and enables the scale to be shifted by more than a decade, to give a top range of roughly 2 200 Hz to 8 800 Hz. *Table 5.1* shows details of the relationships between resistance, frequency, and notes of the keyboard of the *Figure 5.5* circuit.

The musical instrument circuit of *Figure 5.5* can be improved and modified in a number of ways. *Figure 5.6*, for example, shows how the maximum output power of the circuit can be boosted to a few hundred milliwatts by incorporating a complementary emitter-follower stage

Table 5.1. Relationships between resistance, frequency, and notes of the keyboard of the *Figure 5.5* circuit.

Note	*Frequency (Hz)*	*Sum of the Timing Resistor Chain, in Ohms*	*Value of the Incremental Timing Resistor, in Ohms*	*Practical Value or Timing Resistor, using Standard Resistors*
A^3	220.000	20 109 Ω	1 122 Ω	1 kΩ + 120 Ω = R_{25}
$A\#^3$	233.082	18 787 Ω	1 062 Ω	1 kΩ + 68 Ω = R_{24}
B^3	246.942	17 985 Ω	1 002 Ω	1 kΩ = R_{23}
C^3	261.626	16 923 Ω	946 Ω	860 Ω + 86 Ω = R_{22}
$C\#^3$	277.183	15 977 Ω	891 Ω	860 Ω + 33 Ω = R_{21}
D^3	293.665	15 086 Ω	840 Ω	680 Ω + 150 Ω = R_{20}
$D\#^3$	311.127	14 246 Ω	794 Ω	680 Ω + 120 Ω = R_{19}
E^3	329.628	13 452 Ω	750 Ω	680 Ω + 68 Ω = R_{18}
F^3	349.228	12 702 Ω	708 Ω	680 Ω + 27 Ω = R_{17}
$F\#^3$	369.994	11 994 Ω	669 Ω	560 Ω + 100 Ω = R_{16}
G^3	391.995	11 225 Ω	630 Ω	560 Ω + 68 Ω = R_{15}
$G\#^3$	415.305	10 595 Ω	594.6 Ω	560 Ω + 33 Ω = R_{14}
A^4	440.000	10 004.3 Ω	561 Ω	560 Ω = R_{13}
$A\#^4$	466.164	9 443.0 Ω	531 Ω	470 Ω + 56 Ω = R_{12}
B^4	493.883	8 912.3 Ω	501 Ω	470 Ω + 33 Ω = R_{11}
C^4	523.251	8 411.3 Ω	473 Ω	470 Ω = R_{10}
$C\#^4$	554.365	7 938.3 Ω	445.5 Ω	390 Ω + 56 Ω = R_9
D^4	587.330	7 492.8 Ω	420.0 Ω	390 Ω + 27 Ω = R_8
$D\#^4$	622.254	7 072.8 Ω	397.0 Ω	390 Ω + 6.8 Ω = R_7
E^4	659.255	6 675.8 Ω	375.0 Ω	330 Ω + 47 Ω = R_6
F^4	698.456	6 300.8 Ω	354.0 Ω	330 Ω + 22 Ω = R_5
$F\#^4$	739.989	5 946.8 Ω	334.5 Ω	330 Ω = R_4
G^4	783.991	5 612.3 Ω	315.0 Ω	270 Ω + 47 Ω = R_3
$G\#^4$	830.609	5 297.3 Ω	297.3 Ω	270 Ω + 27 Ω = R_2
A^5	880.000	5 000.0 Ω	5 000 Ω	10 kΩ//10 kΩ = R_1

NOTE: Incremental ratio of frequency and resistance = 1.0594631 between the speaker and the op-amp output, and how an adjustable volume control can be included in the design.

Figure 5.7 shows how a vibrato facility can be added to the circuit. Here, IC_2 is wired as a Zener-regulated 8 Hz Wien-bridge sine wave oscillator, and its output waveform is used to apply 8 Hz frequency modulation or vibrato to the main oscillator stage of the instrument. The vibrato depth can be controlled by a 10 kΩ pot, as shown.

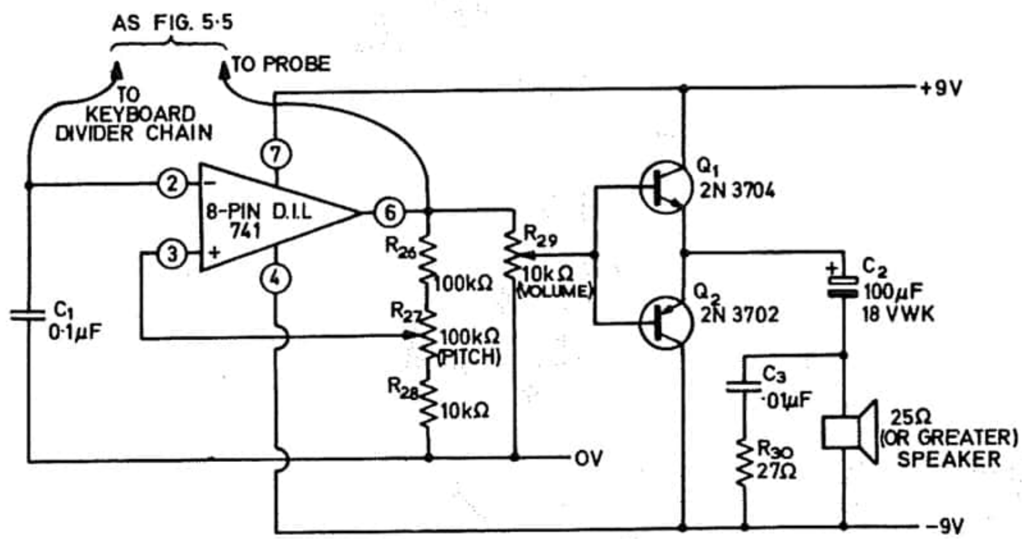
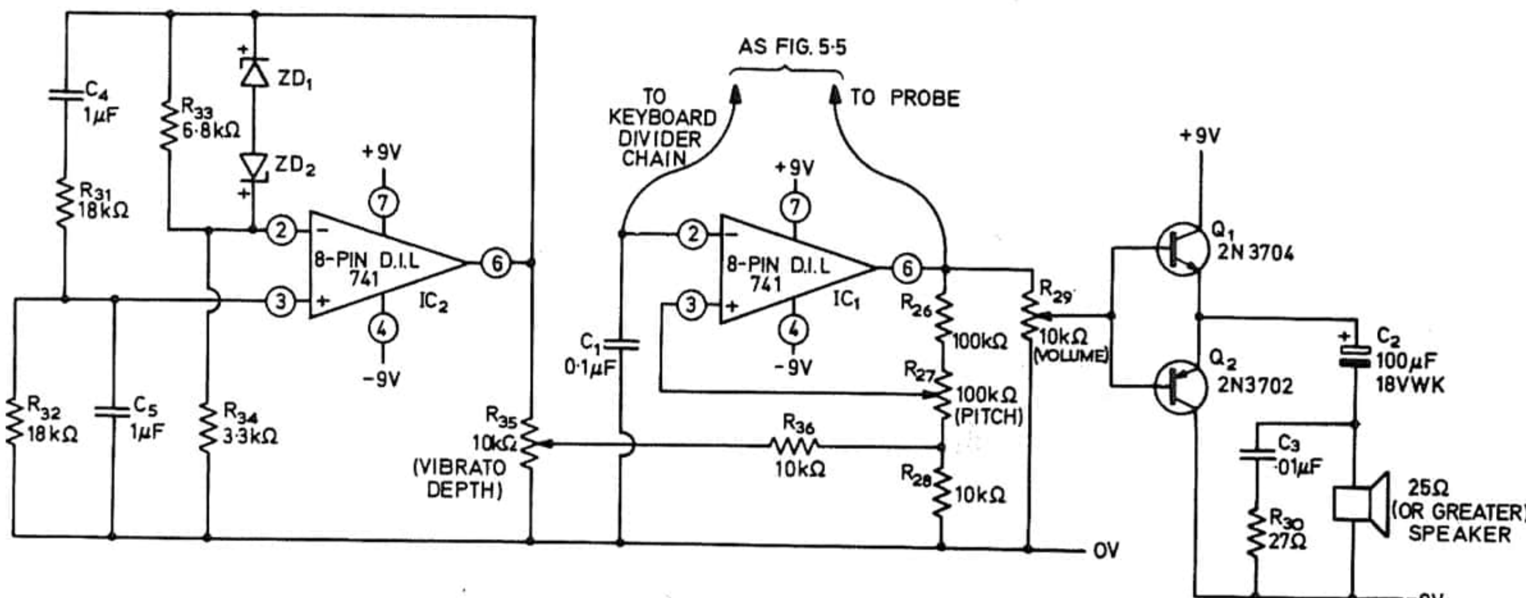


Figure 5.6. Variable-volume musical instrument with boosted output.

Miscellaneous sound generators

The basic relaxation oscillator circuit can readily be adapted for use in a variety of miscellaneous sound generator applications. *Figure 5.8*, for example, shows how it can be made to function as a light-sensitive oscillator or sound generator by simply using a cadmium-sulphide light-dependent resistor (LDR) in the tone-controlling timing resistor position, and *Figure 5.9* shows how it can be made to function as a heat-sensitive oscillator or sound generator by using a thermistor in the same position. Note in the *Figure 5.9* circuit that series resistor R_1 is used to limit the frequency range of the design, and that the frequency range is made variable via R_3. In these two circuits the LDR or thermistor can be any type having a resistance value in the range 500 Ω to 5 MΩ under actual operating conditions, thus enabling the operating frequency to be varied over a 10 000:1 range.

Figure 5.10 shows how the basic relaxation oscillator can be modified for use as a simple metronome, designed to cover the range 30 to 300 beats per minute, and thus encompassing the usual musical tempo range of largo (40 beats per minute) to presto (250 beats per minute). The



$ZD_1 = ZD_2 = 4{\cdot}7$ VOLT ZENER DIODE

Figure 5.7. Musical instrument with built-in vibrato.

circuit generates a rectangular waveform with a mark/space ratio of approximately 100:1, and thus delivers a brief pulse of energy to the speaker in each operating cycle. This energy pulse causes a double click to be heard in the speaker at periodic intervals.

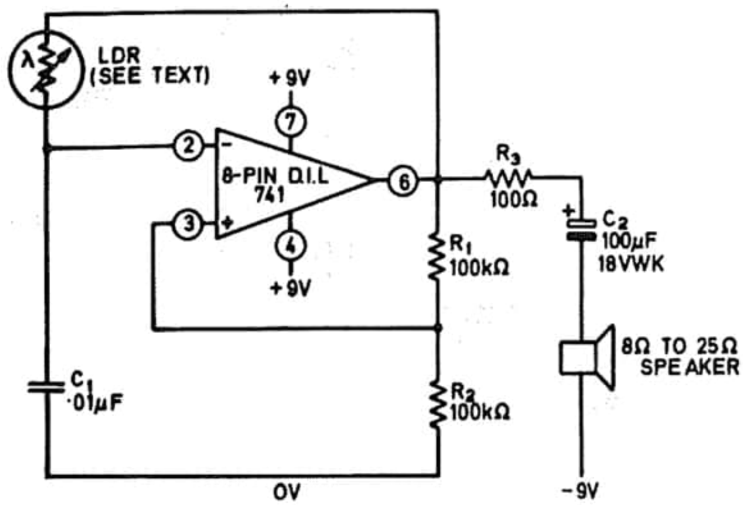


Figure 5.8. Light-sensitive oscillator/sound-generator.

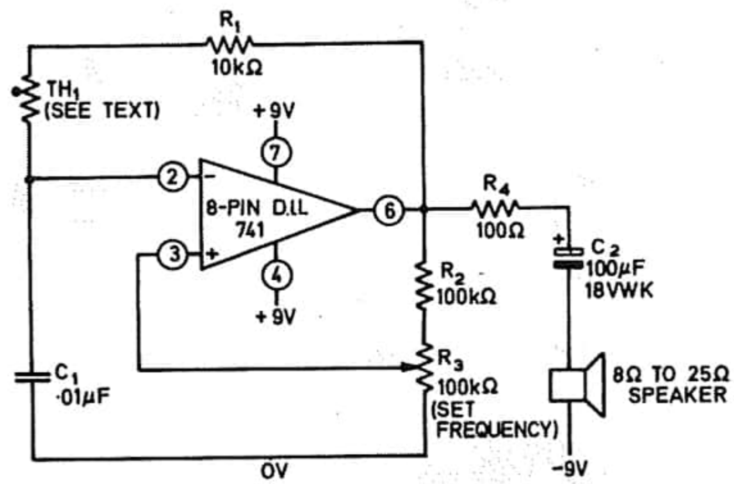


Figure 5.9. Heat-sensitive oscillator/sound-generator, with frequency limiting and adjustable frequency control.

The operating frequency of this circuit is variable via R_5, and the maximum operating period can be precisely pre-set to one beat per two seconds via R_2.

Finally, *Figure 5.11* shows how the relaxation oscillator can be connected for use as a water-activated alarm. In this case a fixed 100 kΩ resistor is used as the tone-controlling element, and is connected to the oscillator via a pair of metal probes. When any reasonably conductive

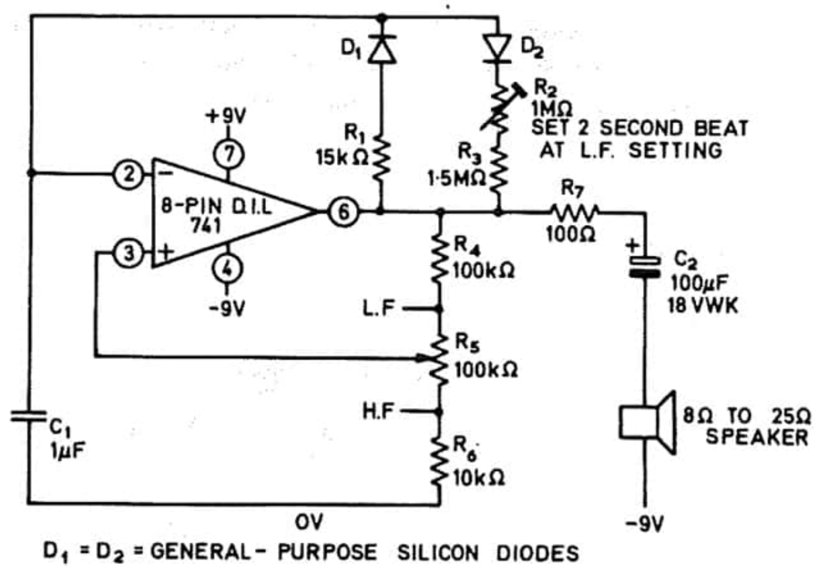


Figure 5.10. Simple metronome, covering 30 to 300 beats per minute.

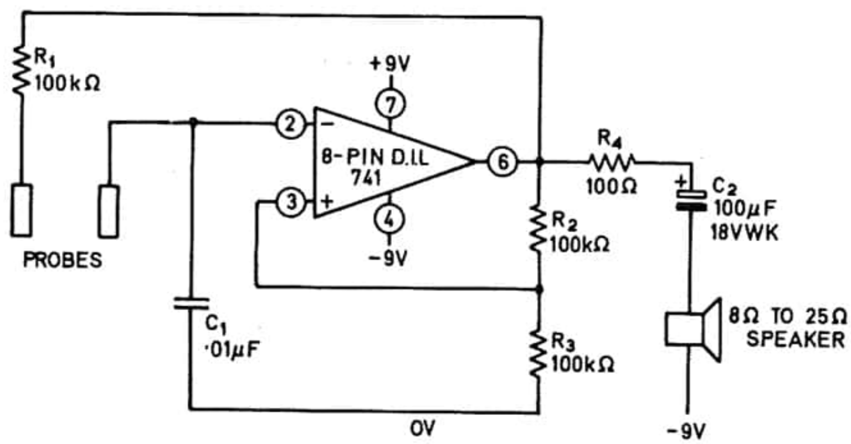


Figure 5.11. Water-activated alarm.

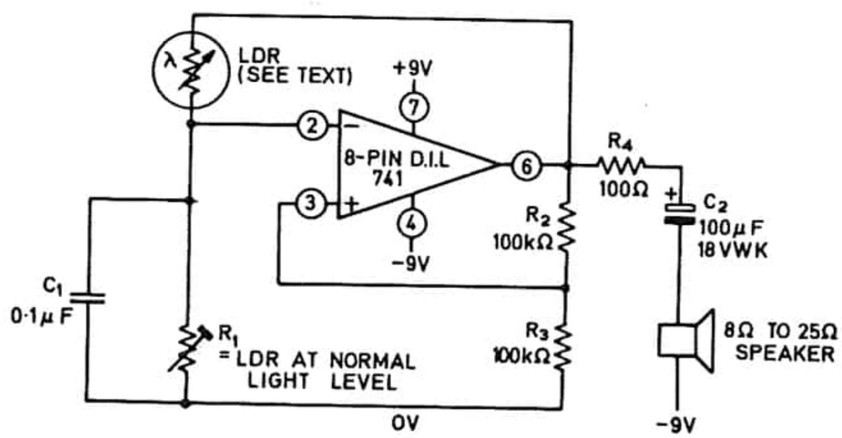


Figure 5.12. Precision light-activated alarm.

liquid comes into contact with both of these probes simultaneously, the circuit oscillates and generates an alarm tone of a few hundred Hz: R_1 limits the upper frequency (with the probes shorted) to about 400 Hz. By using suitably adapted probes, the alarm can be made to sound when water reaches a certain level in a bath or tank, or when flooding occurs in a cellar or basement, or when rain falls across the probes, etc. The circuit draws, typically, a current of less than 1 mA from each supply battery when it is in the standby condition.

Heat and light-activated alarms

It was pointed out earlier in this chapter that the basic relaxation oscillator of *Figure 5.1a* can be made to function as a resistance-activated oscillator by simply wiring a shunt resistor across the circuits main timing capacitor, as shown in *Figure 5.1b. Figure 5.12* shows how the resistance-activated oscillator can be adapted for use as a precision light-activated alarm that turns on when the light intensity exceeds a pre-set level.

In this circuit a cadmium-sulphide LDR is used as the designs tone-controlling resistive element, and variable resistor R_1 is wired across C_1. In practice R_1 is adjusted so that oscillation just commences when the light level rises to the required level: under this condition the LDR presents a resistance fractionally less than that of R_1, so the op-amps negative terminal voltage is able to exceed that of the positive terminal and the circuit oscillates. If the light level falls below the pre-set level the LDR resistance increases above that of R_1, and under this condition the negative terminal voltage is unable to exceed that of the positive terminal, so oscillation ceases. The sensitivity of this circuit is so high that the alarm can be turned on and off by changes in light level too small to be detected by the human eye.

The *Figure 5.12* circuit can be made to function as a dark-activated alarm, which turns on when the light intensity falls below a pre-set level, by simply transposing the R_1 and LDR positions, as shown in *Figure 5.13.* This *Figure 5.13* circuit can be made to function as a sensitive smoke alarm by simply illuminating the LDR via a stabilised light beam and adjusting R_1 so that the circuit just fails to oscillate. If smoke is subsequently injected into the light beam the LDR illumination intensity will fall, and the alarm will sound.

The *Figure 5.12* and *5.13* circuits can be used with any cadmium-sulphide LDRs having resistances in the range 2 kΩ to 2MΩ at the required trigger levels. The alarm frequency can be adjusted, if required, by simply changing the C_1 value: increasing the C_1 value reduces the frequency, and vice versa.

Figure 5.14 shows how the *Figure 5.12* circuit can be made to function as a precision over-temperature alarm by simply using a thermistor in place of the LDR. An under temperature alarm can be made by using a thermistor in place of the LDR of the *Figure 5.13* circuit. The thermistors can be any negative temperature coefficient types having a resistance in the range 2 kΩ to 2 MΩ at the required trigger levels.

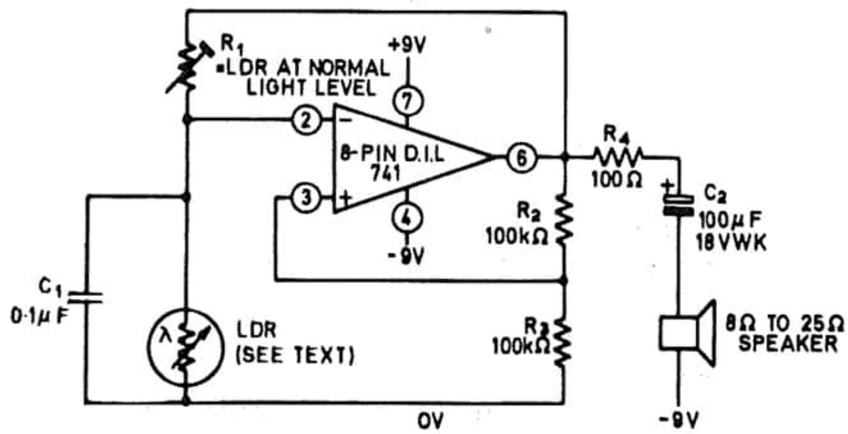


Figure 5.13. Precision dark-activated alarm.

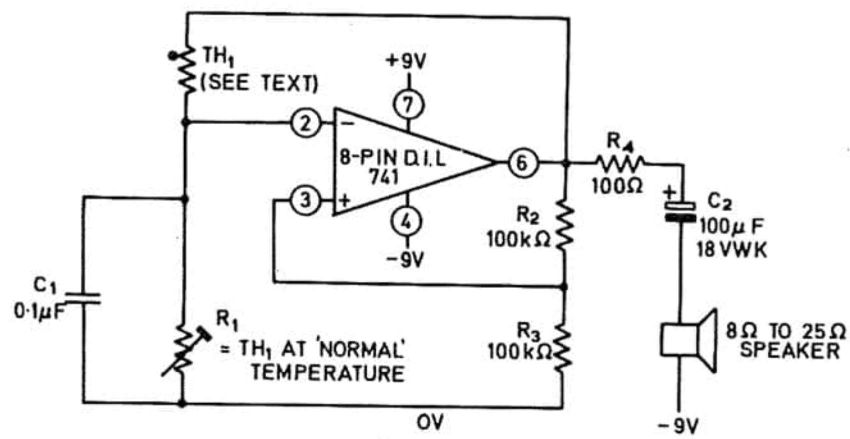


Figure 5.14. Precision over-temperature alarm.

The simple heat and light-activated alarms that we have looked at so far can be modified and adapted in a number of ways to increase their versatility. Their output powers can, for example, be increased to several hundred milliwatts by wiring a simple power-boosted stage between the speaker and the op-amp output terminal, as shown in the high output under-temperature alarm circuit of *Figure 5.15*. Note in this case that the speaker must have an impedance of 25 Ω or greater, due to the limited current-handling capabilities of the specified output transistors.

Again, the circuits can be modified for operation from a single supply battery by using a simple potential divider to give the necessary op-amp

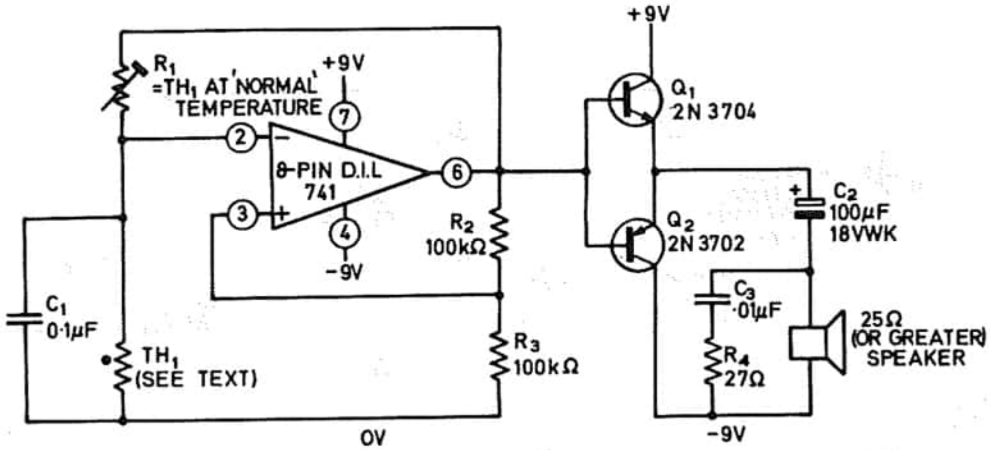


Figure 5.15. **High output under-temperature alarm.**

biasing, as shown by R_5 and R_6 in the single-supply over-temperature alarm circuit of *Figure 5.16*.

If required, both of the above modifications can be applied to a single alarm system, as shown in the single supply, high output, frost or under-temperature alarm circuit of *Figure 5.17*. This particular design can usefully be built into an automobile, with the thermistor mounted low down on the front of the vehicle, for use as an ice hazard warning alarm.

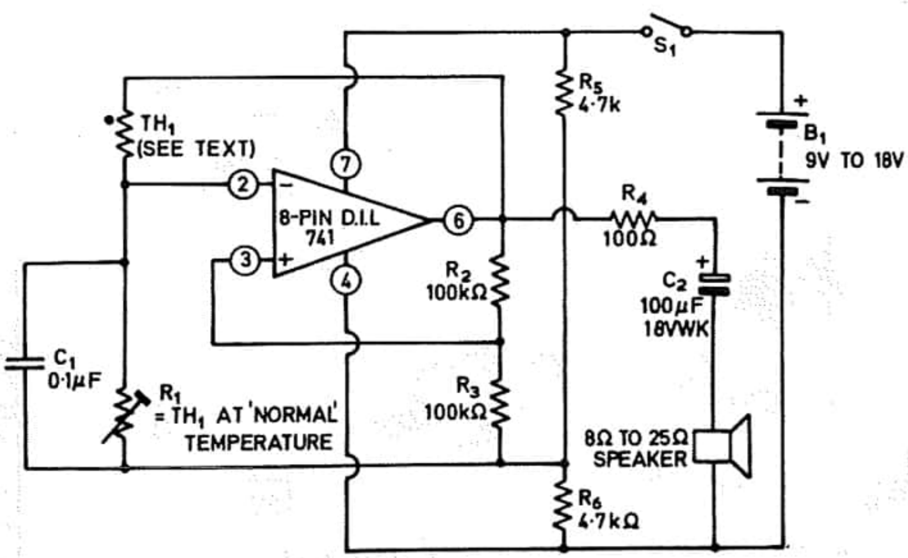


Figure 5.16. **Single supply over-temperature alarm.**

The two-rail and single-rail light and heat alarm circuits can be made to activate a relay as the alarm sounds by using the connections shown in the frost alarm circuits of *Figures 5.18* and *5.19*. The relay contacts can be used to activate auxiliary warning devices or mechanisms such as lights, heaters, motors, etc.

The operating principle of the relay-driving sections of the *Figure 5.18*

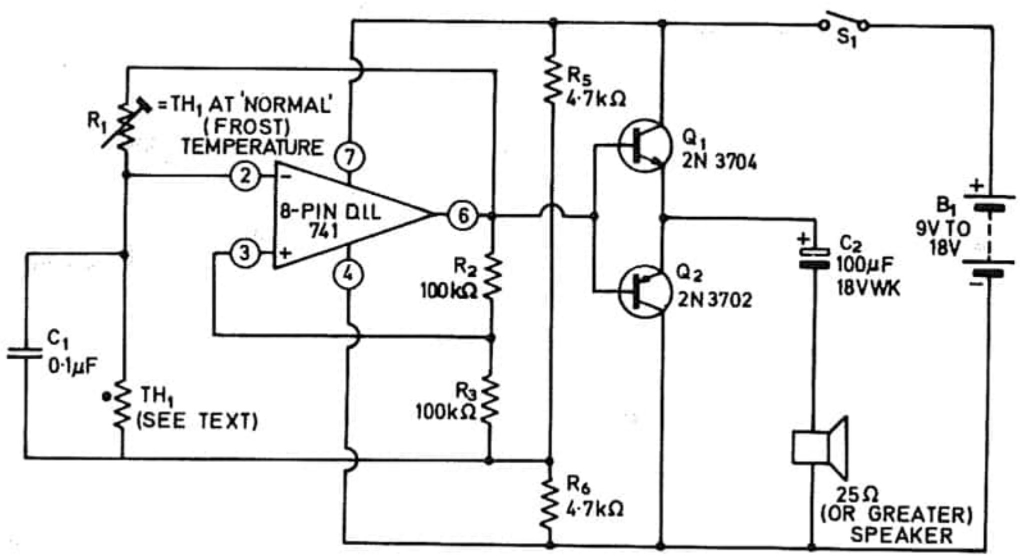


Figure 5.17. Single supply high-output frost alarm.

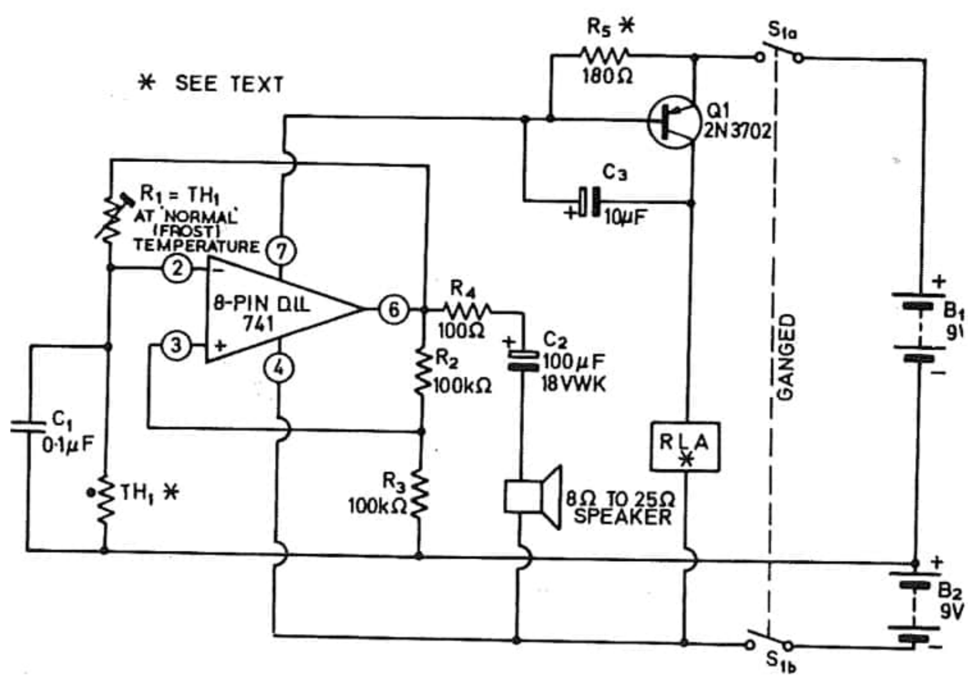


Figure 5.18. Dual supply frost alarm with sound and relay output.

and *5.19* circuits is quite simple. The relay is used as the collector load of Q_1, which is wired as a common emitter amplifier with its base-emitter junction in parallel with 180 Ω resistor R_5, which is wired in series with the positive supply line of the op-amp. Normally, with the alarm on standby, the op-amp draws a quiescent current (from each battery) of less than 1 mA. The current of the positive supply line flows to the op-amp via R_5, so the potential across this resistor is insufficient to bias Q_1 on under this condition, and the relay is off. When the alarm is operating, on the other hand, the circuit current drawn from each

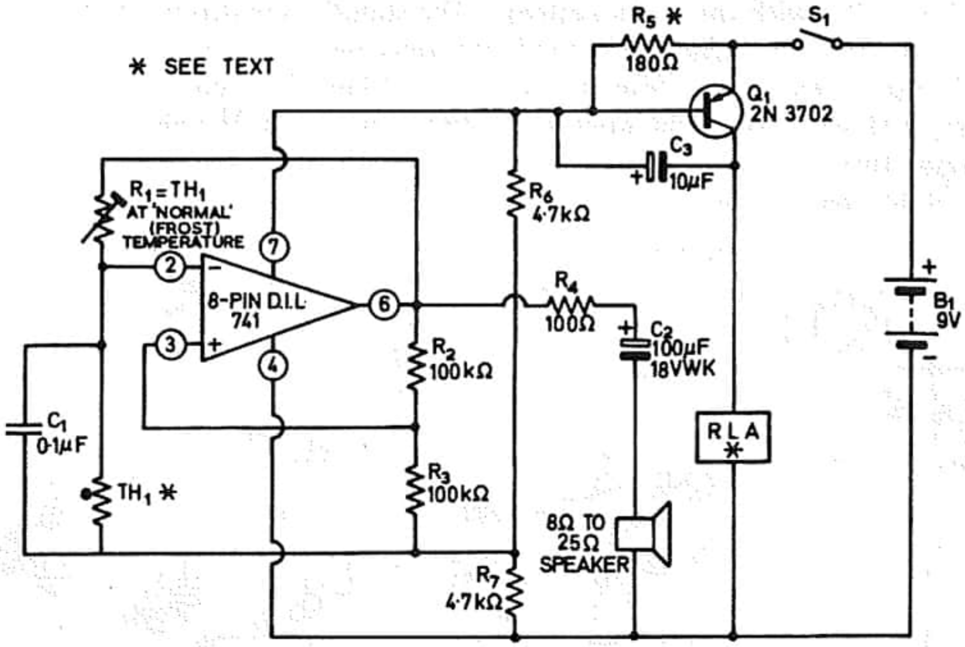


Figure 5.19. **Single supply frost alarm with relay output.**

battery rises to roughly 20 mA, so in this case the R_5 potential drives Q_1 and the relay on, and most of the current reaches the op-amp via the Q_1 base-emitter junction: Q_1 and the relay are thus turned on automatically when the alarm sounds. C_2 is used to differentiate the pulsed collector current of Q_1 under the alarm condition, and converts it to smooth d.c., so the relay operates without chatter.

The relay in each of the above circuits can be any type with a coil resistance greater than 180 Ω, and with a suitable voltage rating. R_5 should have a value low enough not to drive the relay on under quiescent conditions but high enough to turn it on as soon as the alarm starts to oscillate: a value of 180 Ω should prove satisfactory in most cases.

A contact-operated alarm

Finally, to conclude this chapter, *Figure 5.20* shows how the basic op-amp relaxation oscillator circuit can be adapted for use as the basis of a self-latching contact-operated alarm system that can be used as a burglar alarm in the home. In this circuit the op-amp oscillator is adapted for single-supply operation via the $R_4 - R_5$ potential divider, and the complete oscillator is connected in parallel with the coil of relay *RLA*, which is used as the collector load of transistor Q_1. Q_1 is wired as a basic common emitter amplifier, with its base bias derived from the positive supply line via switches S_1 to S_4 and via resistor R_7. The output of the op-amp oscillator is fed to the 25 Ω speaker via power-boosting transistors Q_2 and Q_3. Circuit operation is as follows.

Normally, with the alarm system in the standby condition, switches S_1 to S_3 are open. Under this condition zero bias is applied to the base of transistor Q_1, so the transistor is cut off. Since Q_1 is cut off, zero current flows through the op-amp oscillator circuit, so the alarm is inoperative under this condition, and the circuit consumes only a negligible leakage current.

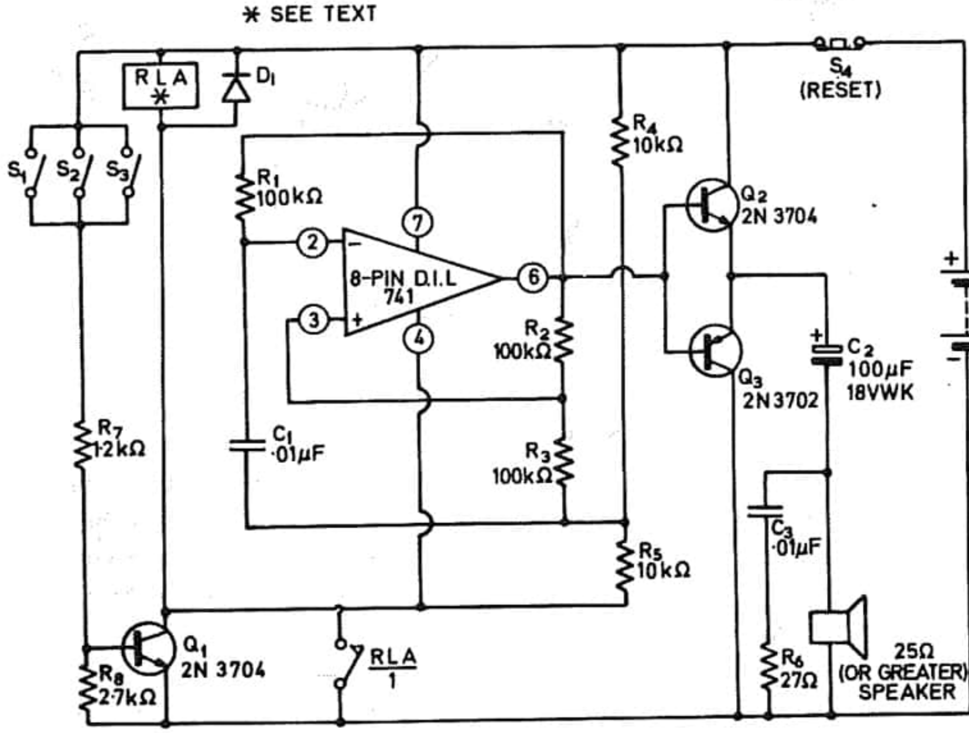


Figure 5.20. Make-to-operate self-latching alarm system.

Suppose that one of the S_1 to S_3 switches is now momentarily closed. As the switch closes it applies base bias to Q_1, and drives the transistor to saturation. As the transistor goes into saturation it operates the relay and causes contacts *RLA*/1 to close, and these contacts then hold the relay in the self-latched state even if switches S_1 to S_3 are subsequently opened. Simultaneously, as power is applied to the relay, power is applied across the op-amp oscillator section of the circuit, and a powerful alarm tone is generated in the speaker. Thus, the alarm operates and self-latches into the ON mode as soon as one or more of the S_1 to S_3 switches is momentarily closed. Once the alarm has latched on, it can be turned off again by operating RESET switch S_4.

In practice, the above circuit can be made to function as a burglar alarm by using microswitches or pressure-pad switches in the S_1 to S_3 positions. The microswitches can be activated by the action of doors or windows opening, and the pressure pads can be activated by the action of stepping onto rugs or carpets, etc. If required, relay *RLA* can be provided with an extra pair of contacts, which can be used to operate auxiliary circuitry such as delayed-action alarm bells, lights, etc. The relay can be any type having a coil resistance greater than 180 Ω and having a voltage rating suitable to the supply voltages used in the circuit. These voltages can have any convenient value in the range 9 V to 18 V. Diode D_1, wired across the relay coil, is a general purpose silicon diode, and is used to protect the circuit against any back e.m.f. that may be generated as the relay operates.