CHAPTER 4

20 OSCILLATOR AND MULTIVIBRATOR PROJECTS

Operational amplifiers can be used in a variety of waveform generating applications. They can readily be made to function as oscillators and multivibrators, and can be used to generate sine waves, square waves, triangle waves, and waves with a variety of ramp and pulse forms. They can readily be used to generate waveforms at repetition rates as low as a few cycles per hour or as high as 20 000 cycles per second.

Twenty useful op-amp oscillator and multivibrator 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.

Sine-wave oscillations

Low frequency sine waves can be generated in a variety of ways. One very simple method is to wire a critically adjusted twin-T network between the output and the input of an inverting operational amplifier, as shown in *Figure 4.1*.

Here, the twin -T network comprises $R_1 - R_2 - R_3 - R_4$ and $C_1 - C_3 - C_4$. In a normal twin-T circuit the network is said to be balanced when its components are in the ratios $R_1 = R_2 = 2(R_3 + R_4)$, and $C_1 = C_2 = C_3/2$. When the network is perfectly balanced it acts as a frequency-dependent attenuator, and gives zero output at a centre frequency equal to $1/6.28 R_1 C_1$, and a finite output at all other frequencies. When the twin-T network is imperfectly balanced, it gives an attenuated but finite output at the centre frequency, and the phase of this output signal depends on the direction of the imbalance: if the imbalance is caused by $(R_3 + R_4)$ being too low in value, the phase of the output is inverted relative to the input.

In the *Figure 4.1* circuit the input of the twin-T network is taken from the output of the op-amp, the output of the twin-T is fed to the inverting input terminal of the op-amp, and R_4 is critically adjusted so that the twin-T gives a small output at the centre-frequency, this output being phase-inverted relative to the input. Thus, zero overall phase inversion takes place between the output and the input of the op-amp at the centre-frequency, and the circuit oscillates at the centre-frequency of the twin-T network. With the component values shown, the circuit oscillates at a frequency of approximately 1 kHz.

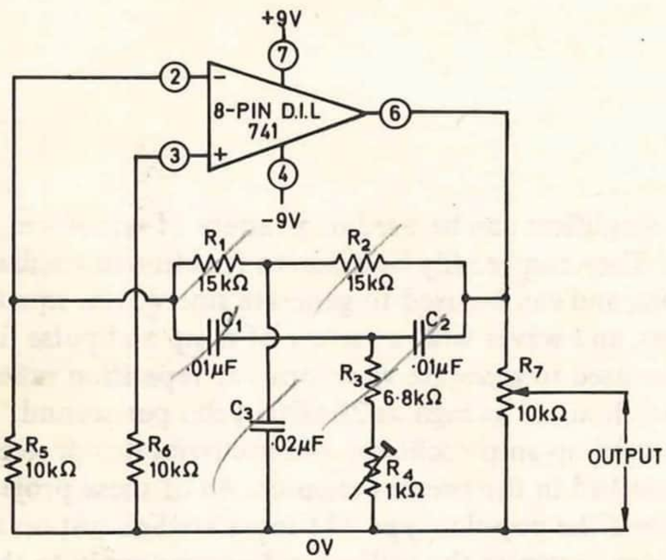


Figure 4.1. 1 kHz twin-T test oscillator.

The output amplitude of the circuit is fully variable from zero to approximately 5 V r.m.s. via R_7. In use, R_4 should be adjusted so that the circuit only just oscillates, under which condition the output typically contains less than 1 % total harmonic distortion. Automatic amplitude control is obtained in this circuit because of the progressive non-linearity of the op-amp as the output signal approaches the clipping level.

An alternative method of automatic amplitude control is shown in the 1 kHz oscillator circuit of *Figure 4.2*. In this case silicon diode D_1 is wired between the output and the input of the op-amp via potential divider R_7. The diode progressively conducts and reduces the voltage gain of the amplifier circuit when the voltage across the diode exceeds a few hundred millivolts, and thus functions as an automatic amplitude control.

To set up the *Figure 4.2* circuit, first set R_7 so that its slider is at the op-amp output end of the pot. Now adjust R_4 so that oscillation ceases, and then slowly advance R_4 just past the point at which oscillation begins again. Under this condition the sine wave output signal has an amplitude of approximately 500 mV peak-to-peak, or 170 mV r.m.s., and all adjustments are complete. R_7 then enables the output signal, which contains negligible distortion, to be varied between 170 mV and 3 V r.m.s.

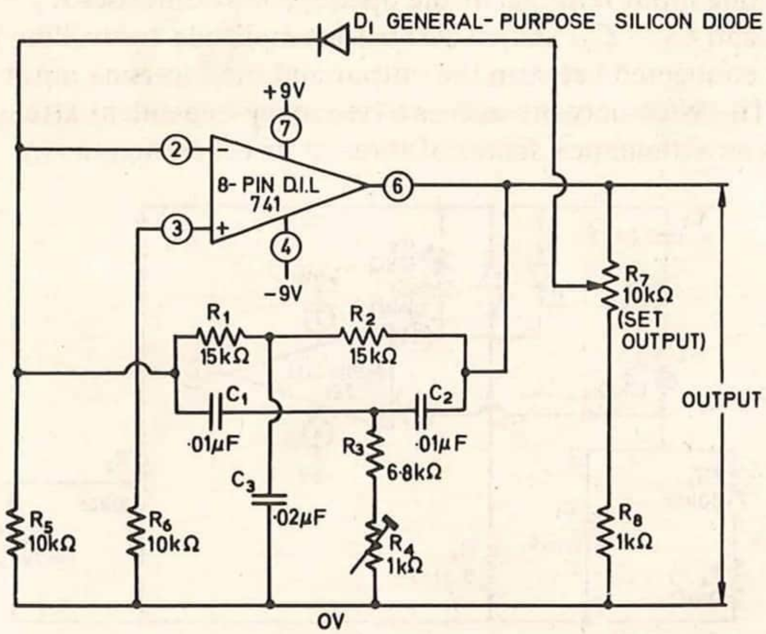


Figure 4.2. Diode-regulated 1 kHz twin-T oscillator.

The *Figure 4.1* and *4.2* circuits act as excellent fixed-frequency oscillators, but are not recommended for variable-frequency use, because of the difficulties of varying three or four twin-T network components simultaneously. Excellent variable-frequency sine-wave oscillators can,

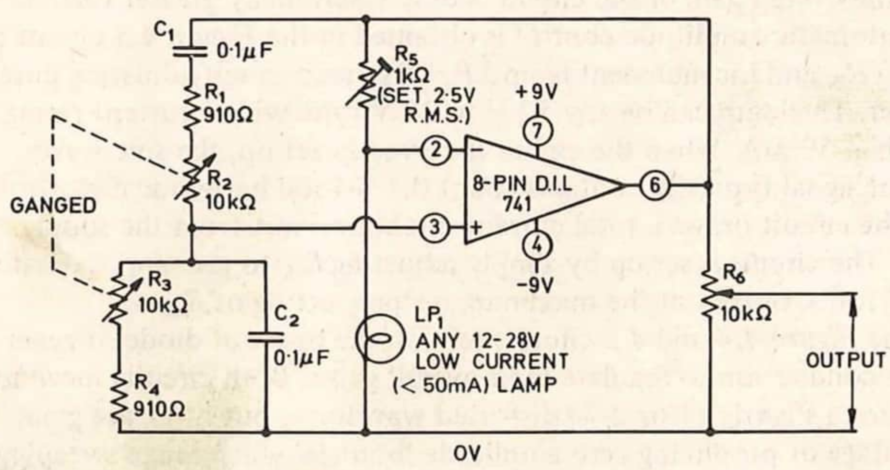


Figure 4.3. 150 Hz - 1.5 kHz Wien-bridge oscillator.

however, be made by using Wien frequency-selective networks in conjunction with op-amps, as shown in the circuits of *Figures 4.3* to *4.5*.

The operating frequencies of these three circuits can be varied over a decade range via twin-gang variable resistors R_2 and R_3: the circuits differ only in the methods used for obtaining automatic amplitude control. In all cases the Wien network is connected between the output and the non-inverting input terminal of the op-amp, and comprises $R_1 - R_2 - R_3 - R_4$ and $C_1 - C_2$, and an automatic amplitude-controlling potential divider is connected between the output and the inverting input of the op-amp. The Wien network acts as a frequency-dependent attenuator that gives an attenuation factor of three at its centre frequency. The

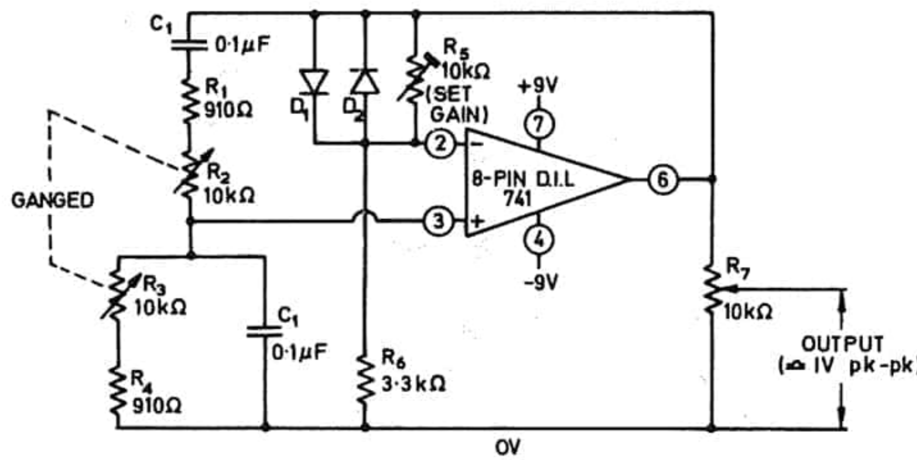


Figure 4.4. Diode-regulated 150 Hz - 1.5 kHz Wien oscillator.

basic requirement for low-distortion sine wave oscillation, therefore, is that the amplitude-controlling section of the circuit must automatically give fractionally less attenuation than the Wien network, and thus ensure that the overall gain of the circuit is only fractionally greater than unity.

Automatic amplitude control is obtained in the *Figure 4.3* circuit by wiring R_5 and incandescent lamp LP_1 in series as a self-adjusting potential divider. The lamp can be any 12 V to 28 V type with a current rating of less than 50 mA. When the circuit is correctly set up, the sine wave output signal typically contains about 0.1 % total harmonic distortion, and the circuit draws a total current of about 6 mA from the supply lines. The circuit is set up by simply adjusting R_5 to give approximately 2.5 V r.m.s. output at the maximum output setting of R_6.

The *Figure 4.4* and *4.5* circuits rely on the onset of diode or zener diode conduction to regulate their overall gains. Both circuits inevitably produce a slightly (1 or 2 %) distorted waveform, but offer the great advantage of producing zero amplitude 'bounce' when range sweeping in variable-frequency circuits. The maximum peak-to-peak output of each circuit is roughly double the breakdown voltage of the semiconductor regulation element. In the *Figure 4.4* circuit the diodes begin to conduct at 500 mV, so this circuit gives a maximum peak-to-peak output of only 1 V. In the *Figure 4.5* circuit, on the other hand, zener diodes ZD_1 and ZD_2 are connected back-to-back and may have values as high as 5.6 V, so the maximum peak-to-peak output may be as high as 12 V or so.

The procedure for setting up the *Figure 4.4* and *4.5* circuits is as follows. First, adjust the SET GAIN control so that the circuit just goes into stable operation, with minimum distortion. Now sweep the frequency band and check that oscillation is obtained over the whole range of the circuit. If necessary, find any weak spots in the band and then adjust the SET GAIN control so that good oscillation is obtained at that spot; the circuit will then work over the whole band. The level stability over the band depends on the tracking accuracy of the $R_2 - R_3$ two-gang resistors, and these should be high quality components for best results.

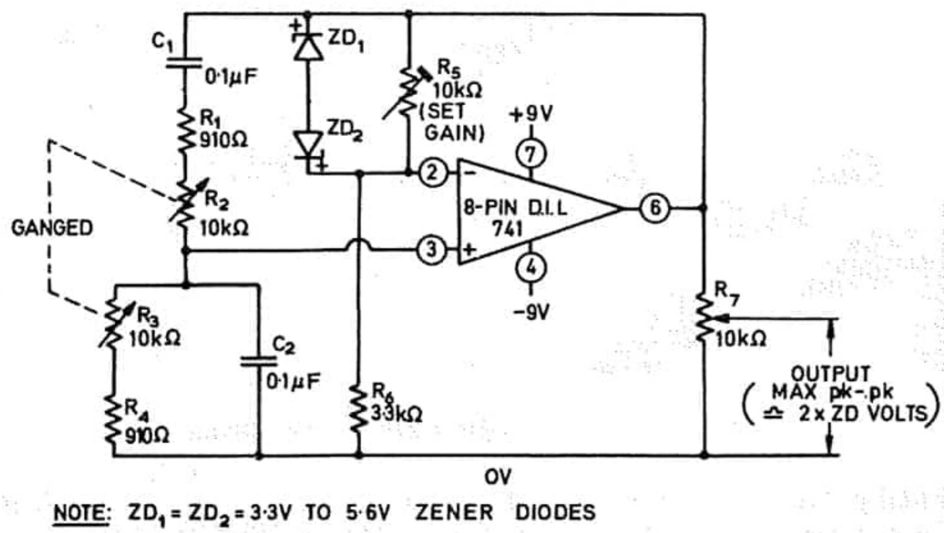


Figure 4.5. Zener-regulated 150 Hz - 1.5 kHz Wien oscillator.

The *Figure 4.3* to *4.5* circuits are designed to cover the range 150 Hz to 1.5 kHz with the component values shown. If required, the frequency range can be changed by using different C_1 and C_2 values; increasing the capacitor values lowers the frequency. The maximum available operating frequency (for a low distortion output) of each circuit is limited to about 25 kHz, due to the slew-rate limitations of the 741 operational amplifier.

The Wien oscillator circuits that we have looked at can be modified in a number of ways to meet specific performance requirements. They can, for example, be adapted for use as fixed-frequency oscillators, or as adjustable fixed-frequency oscillators, or they can be simply adapted to operate from single (rather than dual) power supplies.

Figure 4.6, for example, shows how the *Figure 4.3* circuit can be modified to act as a 1 kHz single supply oscillator. R_7 and R_8 act as a potential divider, to give a quiescent half-supply rail voltage, and C_3 bypasses R_8 to a.c. and thus gives an effective low-impedance supply path for the circuit. Normally, with R_3 and R_4 out of the circuit, oscillation occurs at slightly less than 1 kHz. R_3 and R_4 are used to shunt the R_2 arm of the Wien network, and thus raise the operating frequency to precisely 1 kHz. If necessary, R_3 can be increased or decreased to bring the frequency to precisely 1 kHz if the tuning capacitors are substantially out of tolerance.

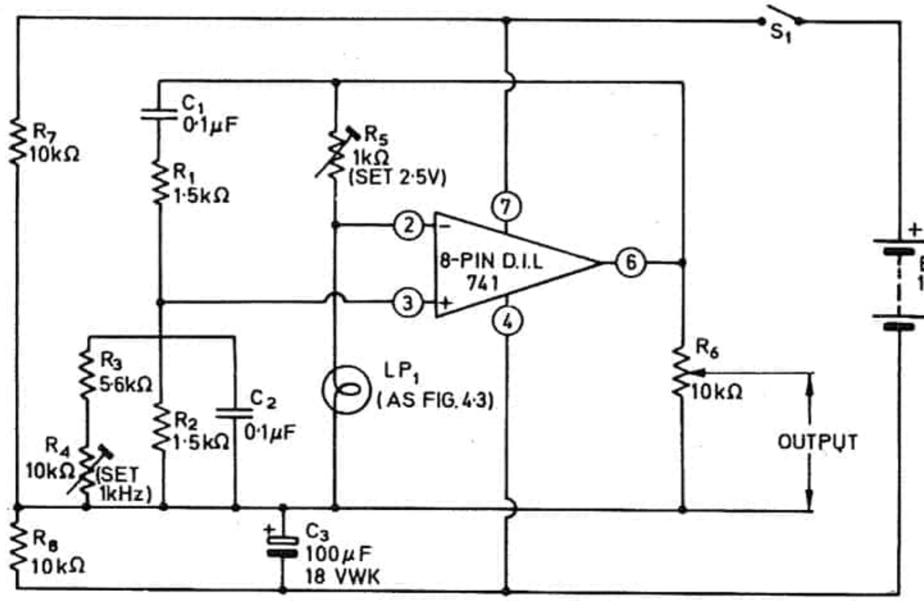
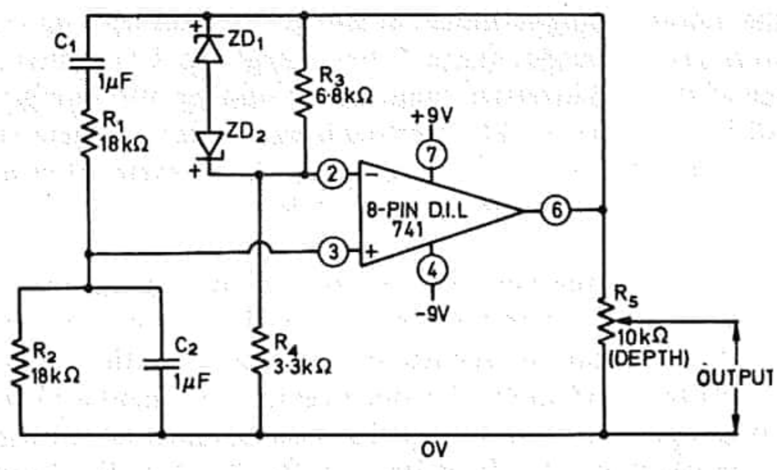


Figure 4.6. Single supply 1 kHz Wien oscillator

Finally, *Figure 4.7* shows how the *Figure 4.5* circuit can be modified to act as a simple 8 Hz vibrato or tremelo oscillator. The Wien network comprises $R_1 - R_2$ and $C_1 - C_2$and zener diodes ZD_1 and ZD_2 and fixed potential divider $R_3 - R_4$ are used to give amplitude control. R_3 has a value slightly greater than double that of R_4, to ensure reliable oscillation with little distortion.

Square-wave generators

Operational amplifiers can be made to act as excellent low-frequency square-wave generators by wiring them in the relaxation oscillator configuration shown in *Figure 4.8a*. Examination of this circuit shows it to contain two potential dividers, each driven from the output of the op-amp, and each with its output going to one or other of the op-amp input terminals. One of these potential dividers is of the resistive type



NOTE: $ZD_1 = ZD_2$ = 3·3V TO 5·6V ZENER DIODES

Figure 4.7. 8 Hz vibrato or tremelo oscillator.

and comprises R_2 and R_3, and feeds its output to the non-inverting input of the op-amp. The other potential divider comprises R_1 and C_1, and generates a timing waveform which is fed to the inverting input of the op-amp. The actual op-amp is used as a regenerative voltage comparator or switch which is activated by the relative levels of the two input signals.

To understand the operation of the basic circuit, assume initially that C_1 is fully discharged and that a regenerative switching action has just taken place in which the op-amp output has switched to a positive saturation level, thus applying a large positive voltage to both potential dividers. Under this condition half of the positive saturation voltage is applied to the non-inverting input of the op-amp via the $R_2 - R_3$ resitive divider, and a rising positive voltage is applied to the inverting input via R_1 and C_1 as C_1 charges up exponentially via R_1 and the positive output of the op-amp. As time passes the rising exponential voltage on the inverting terminal approaches, and eventually exceeds,

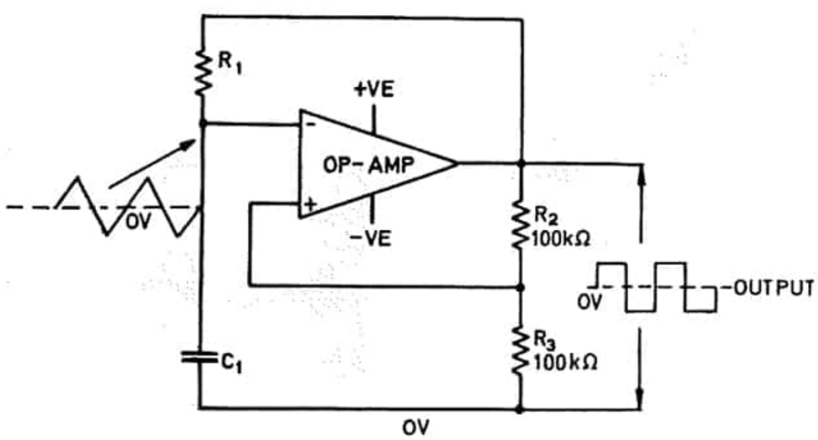


Figure 4.8a. Basic relaxation oscillator circuit.

that on the non-inverting terminal, at which point the op-amp comes out of saturation and its output starts to swing negative. Under this condition the voltage at the non-inverting input of the op-amp also swings negative via R_2 and R_3, but that at the inverting input tends to be held steady by the charge on C_1, the net result being that a sharp regenerative action takes place in which the op-amp output switches abruptly into negative saturation.

At the end of this regenerative stage half of the negative saturation voltage is applied to the non-inverting terminal of the op-amp via $R_2 - R_3$, and C_1 begins to recharge in a negative direction via R_1 and the op-amp output and applies a rising negative exponential voltage to the inverting input terminal. Eventually, this exponential voltage becomes slightly more negative than the voltage on the non-inverting terminal, at which point another regenerative action takes place and the op-amp output switches back to a positive saturation level. The whole timing and switching sequence then repeats ad infinitum. Thus, a series of square waves are generated at the output of the circuit, and a series of approximately triangular waves are developed across C_1.

This basic relaxation oscillator circuit has a number of interesting characteristics. The period of each half-cycle, and thus the operating frequency of the waveform, depends both on the time constant of the $C_1 - R_1$ network and on the voltage dividing ratios of R_2 and R_3, so the operating frequency can be changed by altering any one of these four component values. A wide-range variable-frequency square wave generator can thus be made by making just one of these components variable. The operating frequency of the circuit is dictated almost entirely by the values of the $R_1 - R_2 - R_3 - C_1$ components, and is virtually unaffected by variations in supply rail voltage, so the circuit has execellent frequency stability.

Figure 4.8b shows how the *Figure 4.8a* circuit can be modified to act

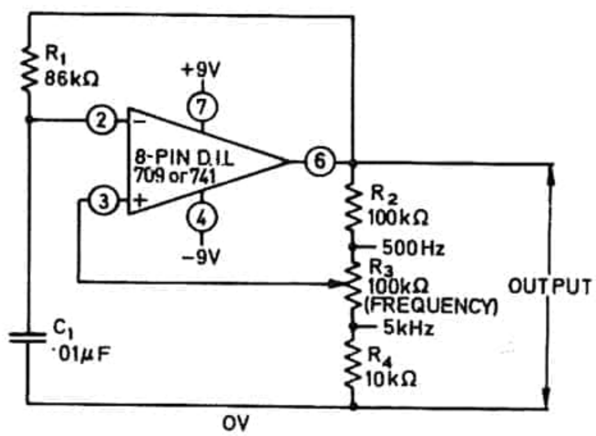


Figure 4.8b. Simple 500 Hz - 5 kHz square wave generator.

as a simple but effective variable-frequency square wave generator covering the approximate range 500 Hz to 5 kHz. In this case the frequency is made variable by adjustment of the division ratio of the $R_2 - R_3 - R_4$ potential divider. The division ratio, and thus the operating frequency, can be varied over a range of one decade. If required, the minimum operating frequency of the circuit can be set to precisely 500 Hz by adjusting the R_1 value, or by replacing R_1 with a 47 kΩ fixed resistor and a 100 kΩ variable resistor in series, as shown in the improved circuit of *Figure 4.9*. This circuit also shows how a 10 kΩ variable pot can be wired across the op-amp output to act as an output amplitude control.

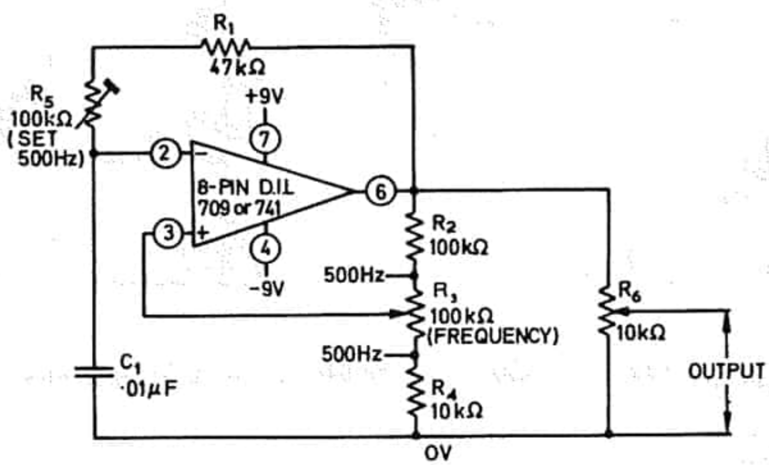


Figure 4.9. Improved 500 Hz - 5 kHz square wave generator.

Figure 4.10 shows how the *Figure 4.9* circuit can be further developed to cover the range 2 Hz to 20 kHz in four switched decades. Ranging is achieved by switch-selecting suitable timing capacitors and resistors. A pre-set variable resistor in each timing arm enables each range to be adjusted to give a precise frequency output at the minimum setting of the frequency control pot, thus giving accurate tracking over all four ranges of the frequency dial.

Finally, *Figure 4.11* shows how the basic square-wave generator can be adapted for use as a push-button tone generator. With the component values shown the circuit generates frequencies of 500 Hz via S_1, 670 Hz via S_2, and 760 Hz via S_3; alternatively frequencies can be obtained by changing the timing resistor values. This particular circuit can readily be used as the basis of a simple tone-signalling system, such as is used for remote-control purposes.

Note in the circuits of *Figure 4.8* to *Figure 4.11* that the op-amps used can be of either the 709 or 741 types. The 709 op-amp has a higher slew rate than the 741, and thus gives the best square-wave output. The

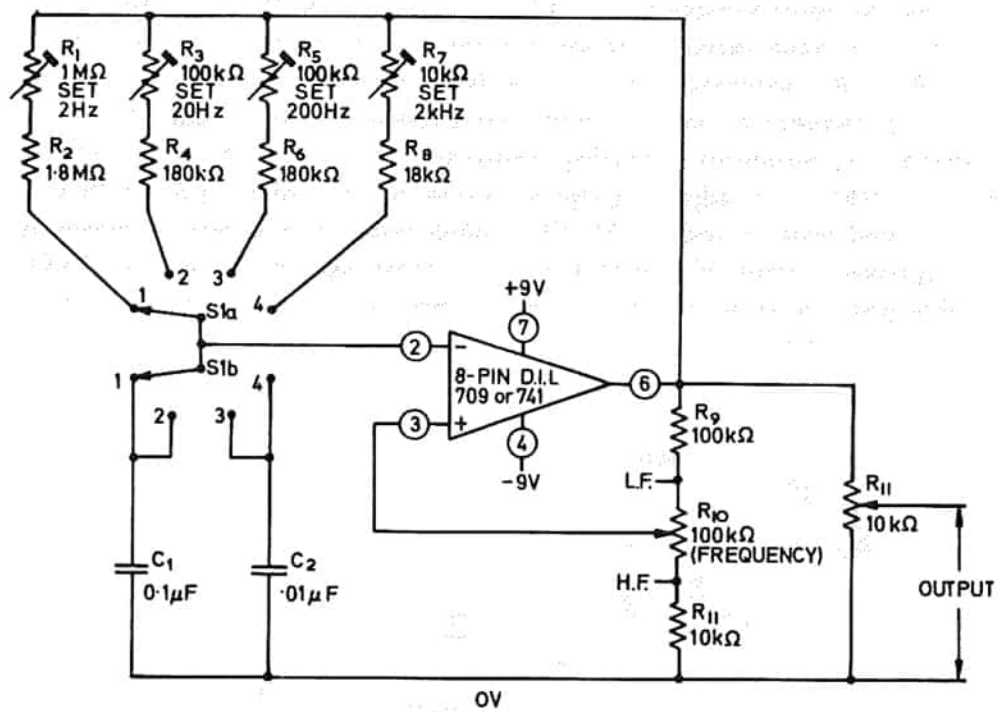


Figure 4.10. 4 decade, 2 Hz - 20 kHz, square wave generator.

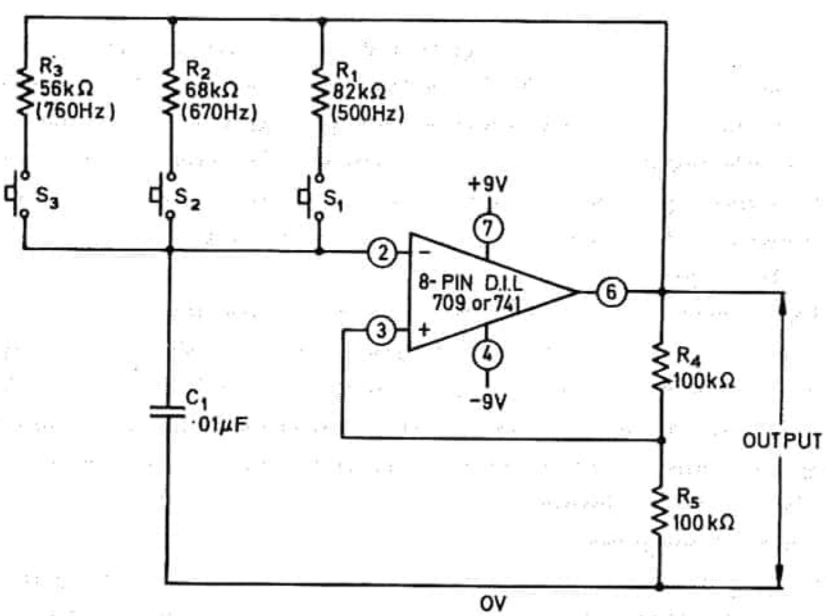


Figure 4.11. Push-button tone generator.

741 gives a good output waveform up to frequencies of about 2 kHz, while the 709 gives a useful waveform up to frequencies of about 20 kHz.

Special waveform generators

The basic relaxation oscillator circuit of *Figure 4.8a* gives a triangle wave output across the timing capacitor, and a square wave output from the op-amp. Both of these waveforms are symetrical, since the positive and negative charging time constants of the circuit are equal. The circuit can be made to give non-symetrical waveforms by using different time constants for the positive and negative half-cycles, as shown in *Figure 4.12*. This circuit gives a rectangular or square wave output that is variable in both frequency and mark/space ratio, the two variable facilities being virtually independent of one another.

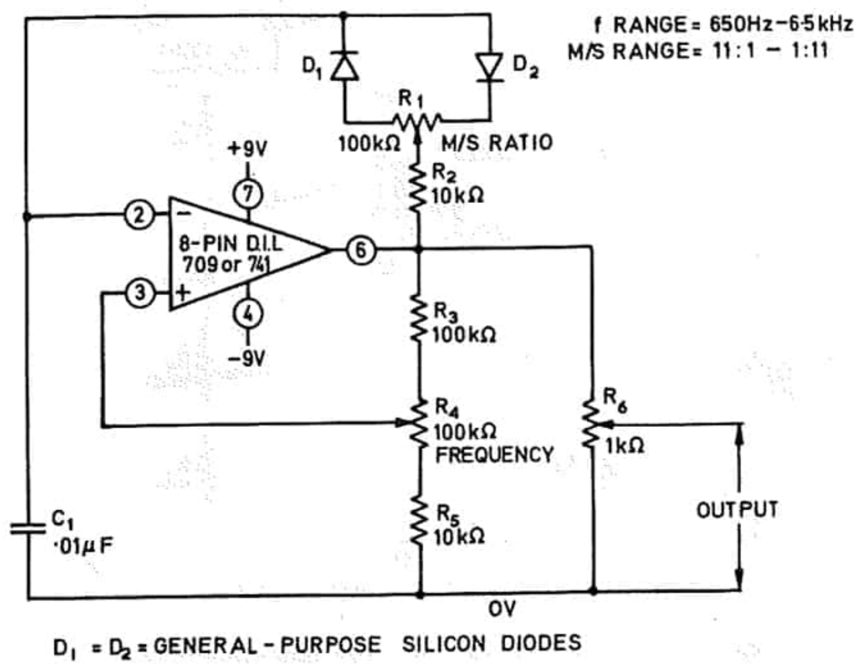


Figure 4.12. Variable frequency and variable m/s ratio, square wave generator.

The variable mark/space ratio facility is obtained via variable pot R_1 and steering diodes D_1 and D_2. On positive charging half-cycles C_1 charges via D_1 and the section of R_1 to the left of the pot slider, and on negative half-cycles it charges via D_2 and the section of R_1 to the right of the slider. Thus, the two time constants of the circuit, and thus the mark/space ratio of the output waveform, are variable via R_1. Note, however, that the sum of the two time constants is also constant, so R_1 has no appreciable effect on the operating frequency of the circuit: the frequency is independently variable via R_4. In practice, variation of the mark/space ratio is restricted to the range 11 : 1 to 1 : 11 via R_1, and

R_1 causes less than 5 % variation in frequency when it is swept through its full range.

With the component values shown, the prototype circuit covers the approximate frequency range 650 Hz to 6.5 kHz. If required, alternative frequency ranges can be obtained by suitable choice of the C_1 values.

Figure 4.13 shows how the *Figure 4.12* circuit can be modified for use as a fixed-frequency (300 Hz) variable-slope ramp generator. The peak-to-peak amplitude of the output ramp is limited to about 1.7 V via the $R_3 - R_4 - R_5$ potential divider to ensure that the waveform is derived from a reasonably linear section of the exponential charging waveform of C_1. R_4 enables the frequency to be set to precisely 300 Hz, although alternative frequencies can, of course, be obtained by using suitable values of C_1.

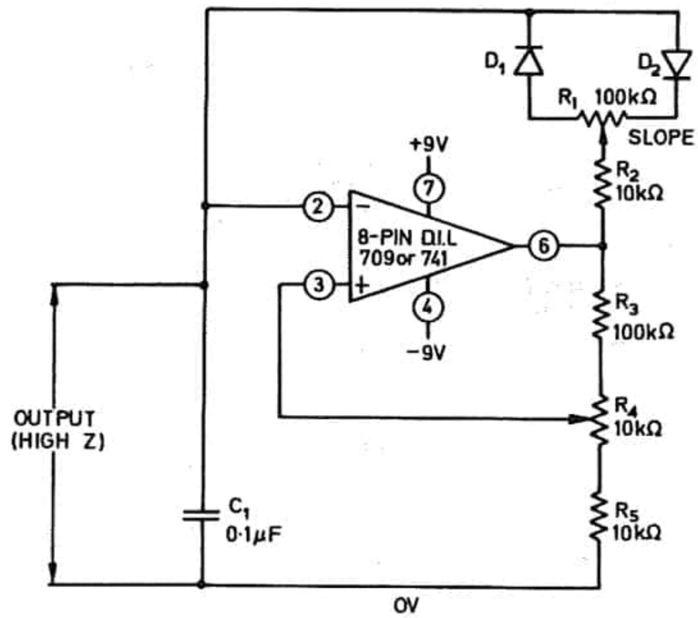


Figure 4.13. 300 Hz variable-slope ramp generator.

The slopes of the output waveform are controlled by R_1. The period of the complete waveform is fixed at 3.33 ms, and R_1 enables the rising (or falling) part of the slope to be varied from approximately 0.3 ms to 3 ms. Note that this circuit has a high output impedance, so the output should be taken to low impedance loads via a suitable buffer stage, such as a unity-gain non-inverting operational amplifier or voltage follower.

The basic relaxation oscillator circuit of *Figure 4.8a* generates a ramp waveform directly from timing capacitor C_1. Since this capacitor is charged exponentially, the ramp output waveform is inevitably slightly non-linear, the degree of non-linearity being proportional to the amplitude of the output signal. A far better system of generating a ramp waveform is shown in *Figure 4.14*. This circuit generates excellent ramp and square waveforms over the frequency range 100 Hz to 1 kHz. The frequency range can be extended by using alternative values of C_1.

The *Figure 4.14* circuit is made up of two sections, these being an integrator (IC_1) and a differential voltage comparator switch (IC_2). To understand the operation of the circuit, assume initially that C_1 is fully discharged and that IC_2 has just switched into the positive saturation state. Under this condition a positive charging voltage is applied to integrating network $R_3 - R_4 - C_1$ via variable potential divider $R_1 - R_2$, so a negative-going linear ramp begins to be generated at the output of IC_1, and is fed to the non-inverting input terminal of IC_2 via R_7. Simultaneously, the positive saturation output voltage of IC_2 is also fed to the IC_2 non-inverting input terminal via R_8.

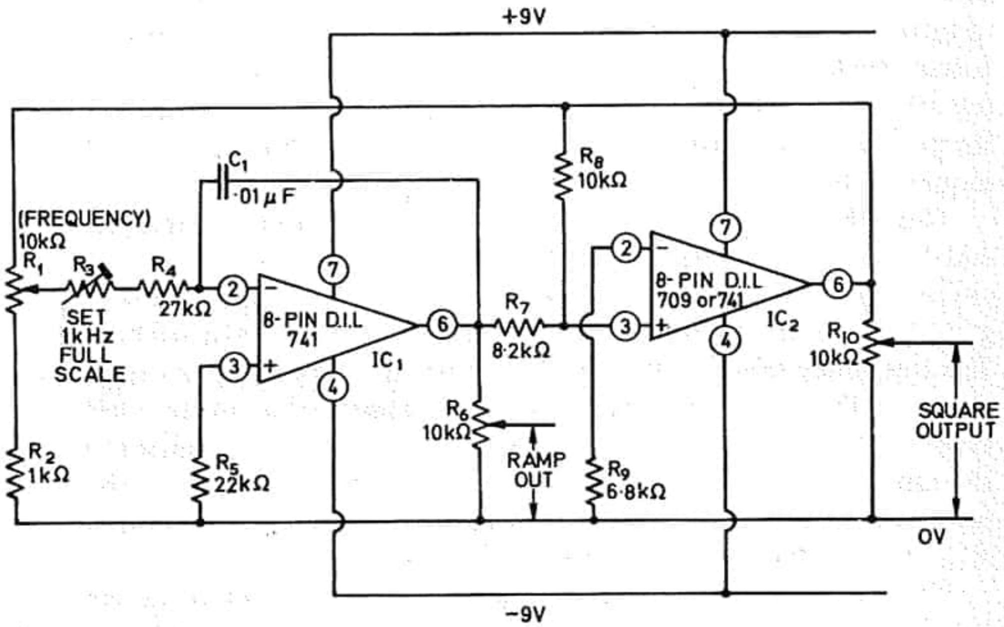


Figure 4.14. 100 Hz - 1 kHz, ramp/square function generator.

Now, R_7 and R_8 are effectively connected as a potential divider between the positive saturation output voltage of IC_2 and the negative ramp output voltage of IC_1, and at this particular stage of the circuit operation the negative ramp is of low amplitude, so the net voltage at the $R_7 - R_8$ junction is distinctly positive. This positive voltage is fed to the non-inverting input of IC_2, which is effectively connected as a non-inverting open-loop d.c. amplifier, so the output of IC_2 is driven to saturation under this condition, as we have already seen.

As time passes, the magnitude of the negative output ramp of IC_1 steadily increases, and the voltage at the $R_7 - R_8$ junction becomes steadily less positive, until eventually the input voltage to the non-inverting terminal of IC_2 falls to zero. At this point IC_2 comes out of saturation and its input begins to drop towards zero. This downward voltage swing is fed back to the input of IC_2 via R_8, and an abrupt regenerative action takes place in which IC_2 switches sharply into negative saturation.

As IC_2 goes into negative saturation the charging voltages on the $R_3 - R_4 - C_1$ integrating network is reversed, so a linear positive-going ramp begins to be generated at the output of IC_1, and simultaneously the voltage at the top of R_8 is switched to a negative saturation value. Thus, the voltage of the $R_7 - R_8$ junction becomes distinctly negative under this condition, and IC_2 is held in negative saturation.

As time passes, the magnitude of the positive output ramp of IC_1 steadily increases, and the voltage at the $R_7 - R_8$ junction becomes steadily less negative, until eventually the input voltage to the non-inverting terminal of IC_2 falls to zero. At this point IC_2 again comes out of saturation and its output begins to drop towards zero. This downward voltage swing is fed back to the input of IC_2 via R_8, and an abrupt regenerative action again takes place, but in this instance IC_2 switches sharply back into positive saturation. The whole timing and switching sequence then repeats ad infinitum.

Thus, the *Figure 4.14* circuit generates a linear ramp output from IC_1 and a square wave output from IC_2. The operating frequency of the circuit can be varied from 100 Hz to 1 kHz via R_1, the frequency being greatest when the R_1 slider is set to the $R_1 - R_2$ junction end of the pot. The frequency range of the circuit can be varied by using alternative C_1 values. If the frequency range is increased appreciably above 2 kHz, a type 709 op-amp should be used in the IC_2 position. The magnitude of the ramp output is variable via R_6, up to a maximum value of about 11 V peak-to-peak. The magnitude of the square-wave output is variable via R_{10}, up to a maximum of about 16 V peak-to-peak.

The linear output ramp of the *Figure 4.14* circuit can be converted into a sine-wave or into a variable mark/space ratio square-wave with the aid of suitable adaptor circuits. The circuit of a variable mark/space ratio adaptor is shown in *Figure 4.15.* Here, the op-amp is wired as an open-loop voltage comparator, and has one input applied from the ramp output of *Figure 4.14* and the other applied from a variable potential divider that is wired between the positive and negative voltage supply lines. The op-amp switches into positive or negative saturation each time that the ramp voltage goes more than a few millivolts below or above the reference voltage set on the non-inverting input via R_2. By adjusting the reference voltage, therefore, the op-amp can be made to change state at any point on the ramp waveform, and a variable mark/space ratio square-wave is thus available at the output of the op-amp.

The circuit of the sine wave adaptor is shown in *Figure 4.16*. Here, the ramp waveform is fed into a resistor-diode matrix via adjustable

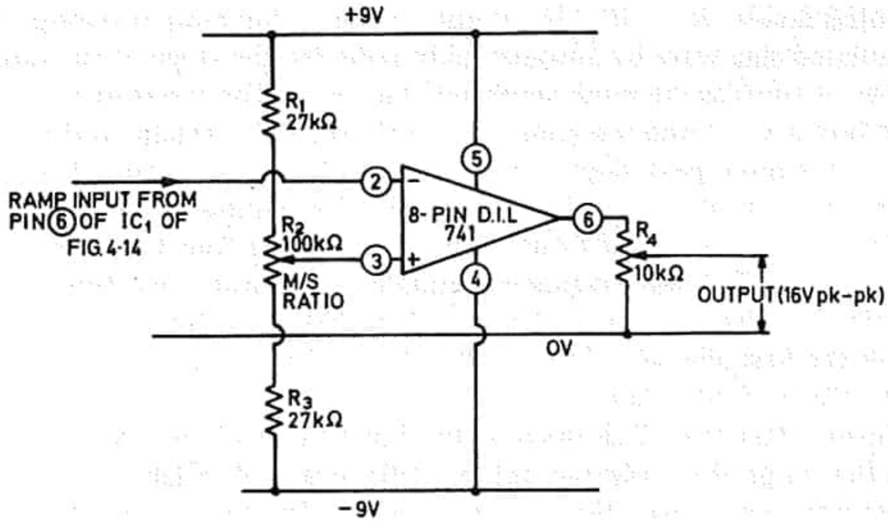


Figure 4.15. Variable m/s-ratio adaptor for function generator (see *Figure 4.14*).

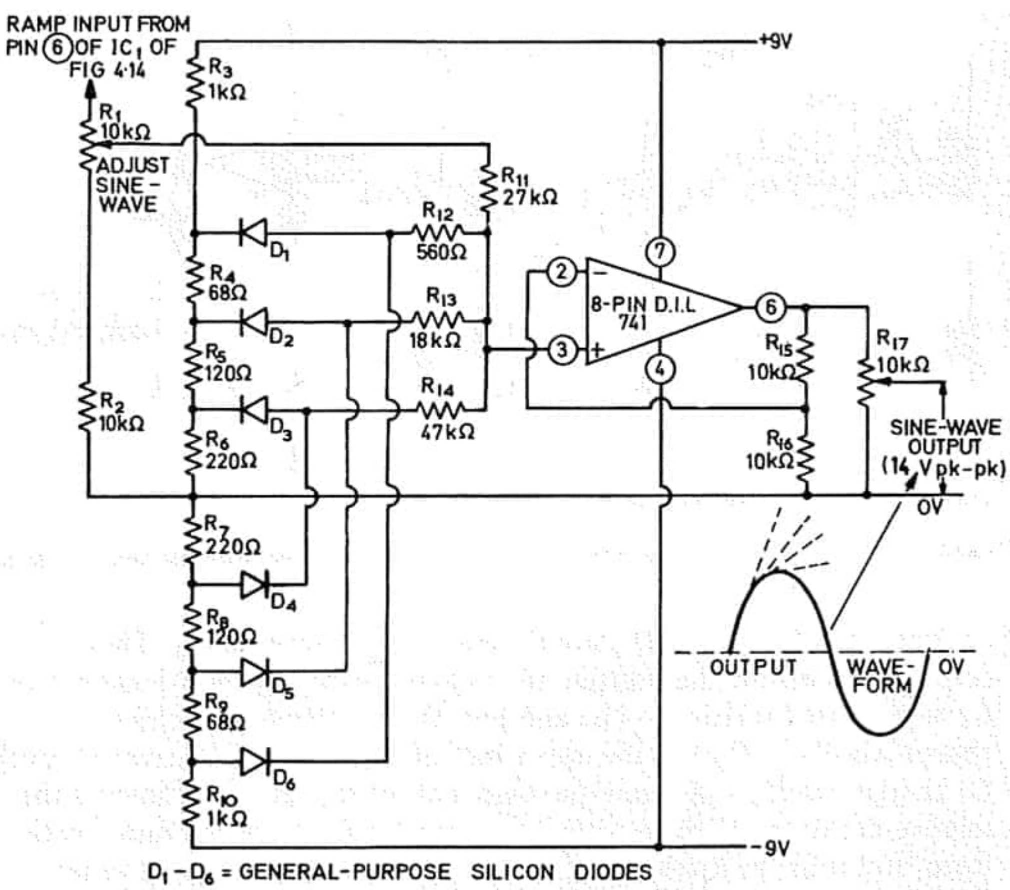


Figure 4.16. Sine wave adaptor for function generator of *Figure 4.14.*

potential divider $R_1 - R_2$. The matrix converts the ramp waveform into a simulated sine wave by automatically reducing the slope of the ramp in a series of steps as the ramp amplitude increases. The resulting waveform is fed into a x 2.2 non-inverting d.c. amplifier, and is finally available with a maximum peak-to-peak amplitude of 14 V across variable output control R_{17}. As shown in the diagram, the final output waveform can be represented by a series of straight lines, there being four lines to each quarter cycle. The waveform approximates a sine wave, and typically contains less than 2 % total harmonic distortion: R_1 should be adjusted to give the best sine wave shape when the inverter is initially connected to the *Figure 4.14* circuit.

Finally, *Figure 4.17* shows how the *Figure 4.14* circuit can be modified to produce a linear ramp waveform with a variable slope, or a square wave with a variable mark/space ratio. The two circuits are similar, except that the integrator charging network of the *Figure 4.17* circuit

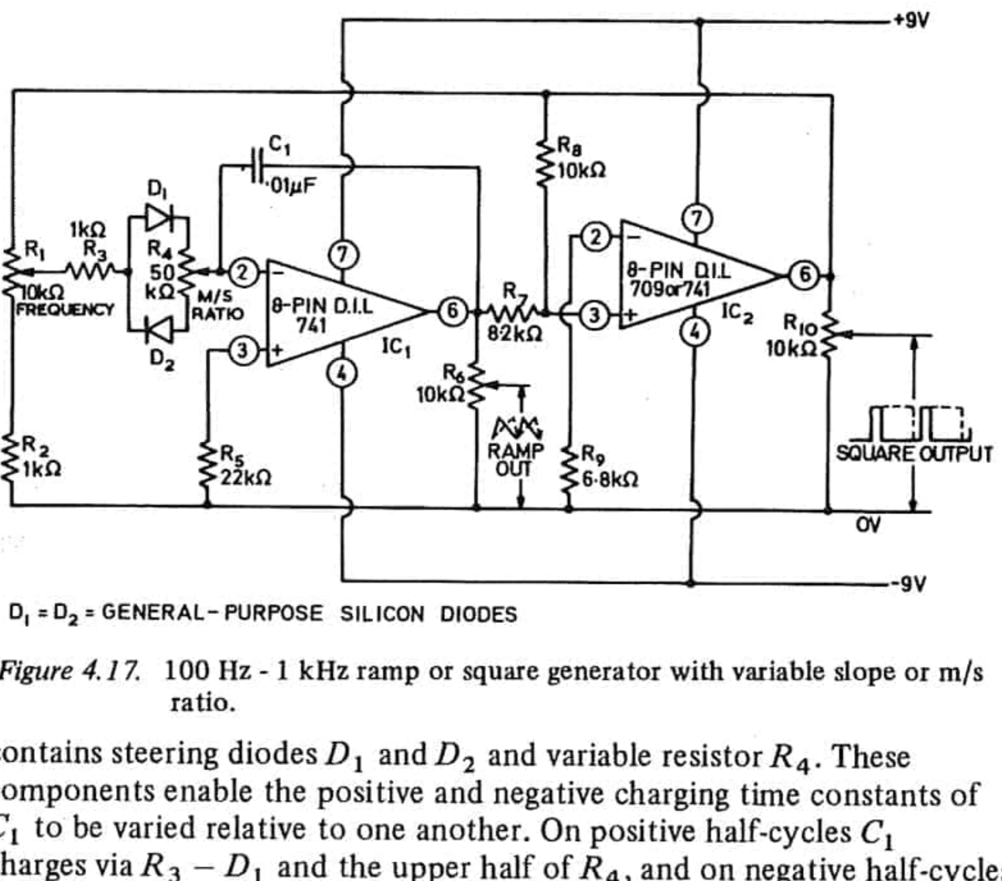


Figure 4.17. 100 Hz - 1 kHz ramp or square generator with variable slope or m/s ratio.

contains steering diodes D_1 and D_2 and variable resistor R_4. These components enable the positive and negative charging time constants of C_1 to be varied relative to one another. On positive half-cycles C_1 charges via $R_3 - D_1$ and the upper half of R_4, and on negative half-cycles C_1 charges via $R_3 - D_2$ and the lower half of R_4. R_4 thus enables the relative durations of the positive and negative slopes of the ramp waveform, and thus the mark/space ratio of the square wave, to be varied without appreciably effecting the operating frequency of the circuit: The operating frequency is independently variable via R_1.

Multivibrator circuits

Operational amplifiers can usefully be employed in a number of multivibrator applications. *Figure 4.18*, for example, shows how an op-amp can be connected to form a simple bistable multivibrator that is used to give push-button ON-OFF operation of a relay, or of a lamp or similar resistive load.

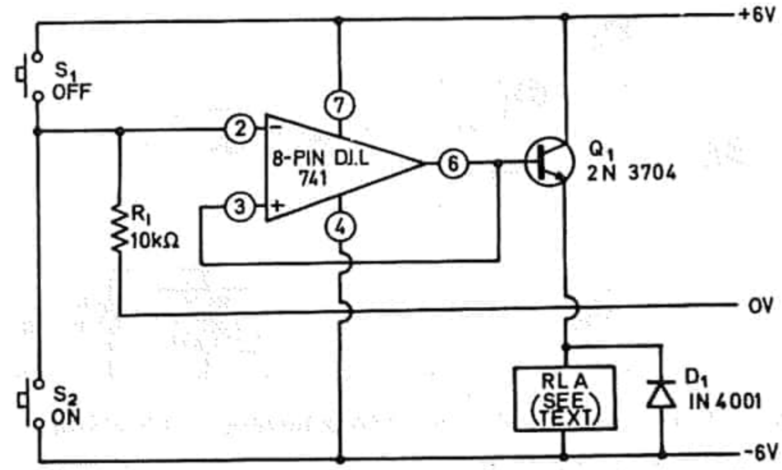


Figure 4.18. **Simple manually triggered bistable multivibrator, with relay output.**

The op-amp in this circuit acts effectively as an electronic switch, its output being in either a positive or negative saturation state. To understand the operation of the circuit, assume initially that the op-amp output is in positive saturation, and S_1 and S_2 are both open. Under this condition the negative terminal of the op-amp is grounded via R_1, and the positive terminal is connected directly to the positive saturation voltage, so the op-amp is locked in the positive saturation state and the relay is driven on by emitter follower Q_1.

Suppose now that S_1 is momentarily closed, briefly shorting the negative terminal directly to the positive supply line. Under this condition the positive terminal momentarily becomes negative relative to the negative terminal, so the op-amp switches into negative saturation, and the relay and Q_1 turn off. Since the positive terminal is connected directly to the op-amp output, the op-amp automatically locks into the negative saturation state, and remains locked once S_1 is released.

Finally, suppose that S_2 is now momentarily closed, briefly shorting the negative terminal to the negative line. Under this condition the positive terminal momentarily becomes positive relative to the negative terminal, so the op-amp switches back into positive saturation and turns the relay on again, thus completing the cycle of events. The relay can thus be turned on by briefly closing S_2, and can be turned off by briefly closing S_1.

Note that the *Figure 4.18* circuit makes use of two 6 V supply sources. The circuit can be modified for operation from a single 12 V supply, if required, by using the connections shown in *Figure 4.19*. In this case R_2 and R_3 act simply as a potential divider across the supply to give a common reference potential of 6 V to the negative terminal of the op-amp.

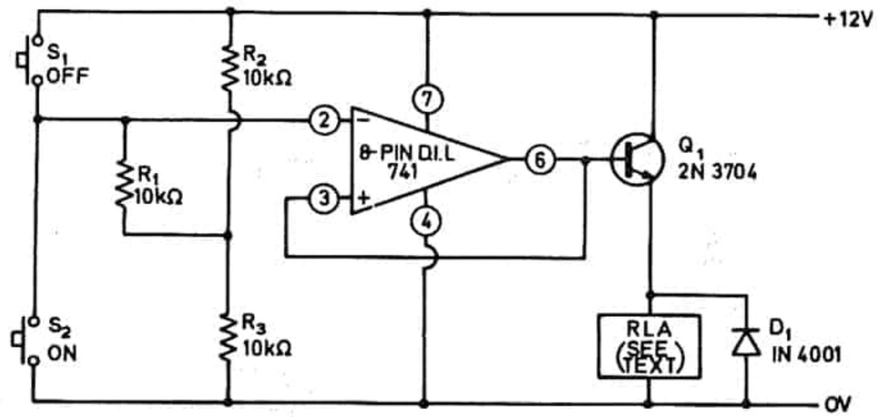


Figure 4.19. Single supply relay-driving bistable multivibrator.

Finally, *Figure 4.20* shows the circuit of a simple manually-triggered relay-driving monostable multivibrator. To understand the circuit operation, assume initially that S_1 is open, and the circuit is in a quiescent state. Under this condition the positive terminal is grounded via R_3, and the negative terminal is held at a small positive potential via $R_1 - R_2$, so the op-amp output is in a state of negative saturation, and the relay is held off via emitter follower Q_1. C_1 is charged up in such a way that its R_3-end is several volts positive relative to its Q_1-base end.

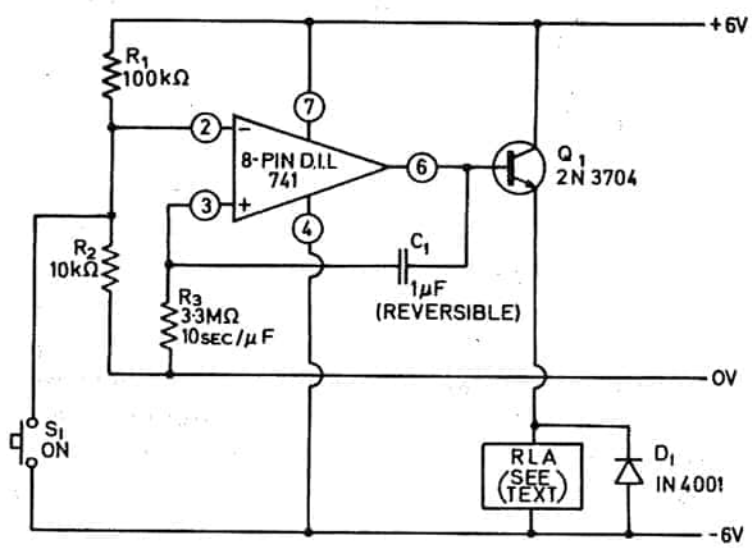


Figure 4.20. Simple 10 s relay-driving monostable multivibrator.

Suppose now that S_1 is momentarily closed, briefly connecting the negative terminal of the op-amp to the negative supply line. Under this condition the negative terminal momentarily becomes negative relative to the positive terminal, so the op-amp output swings into positive saturation and drives the relay on via Q_1. As the op-amp output swings into positive saturation it carries the C_1 charge with it, thus forcing the positive terminal to swing to a positive potential of approximately 10 V, thereby ensuring that the op-amp is locked in the positive saturation state even when S_1 is released. C_1 then slowly starts to discharge via R_3, and the positive terminal voltage decays slowly towards zero. Eventually, after a pre-set delay, the positive terminal voltage falls below the negative terminal voltage (assuming that S_1 is open at this point), and at this stage the op-amp again switches back into negative saturation and turns the relay off. The operating sequence of the circuit is then complete.

Thus, the relay in the *Figure 4.20* circuit turns on as soon as S_1 is momentarily operated, but turns off again automatically after a pre-set delay. The circuit gives a delay of approximately 10 s per microfarad of C_1 value, and thus gives a delay of 10 s with the component values shown. Note that C_1 must be a non-polarised type of capacitor.

The relays used in the *Figures 4.18* to *4.20* circuits can be of any 12 V types with coil resistances greater than 180 ohms or so. If required, resistive loads such as lamps can be used as loads in place of the relays.