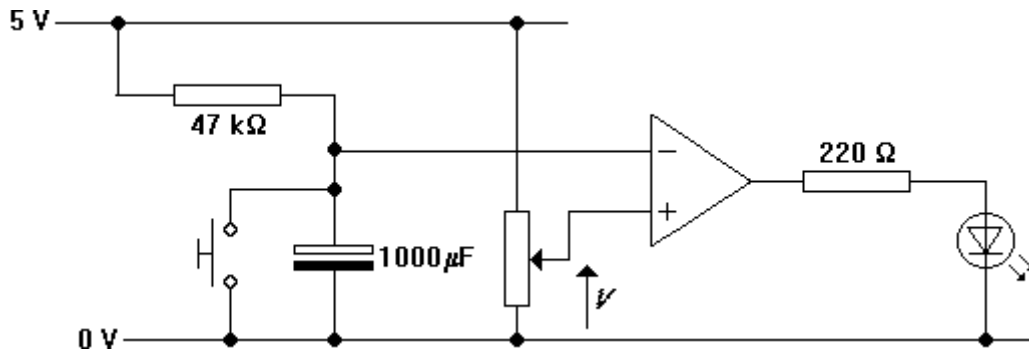


### Measuring time delays

You are going to find out how good the formula  $t = \tau \ln(V_0/V)$  is at predicting time delays.

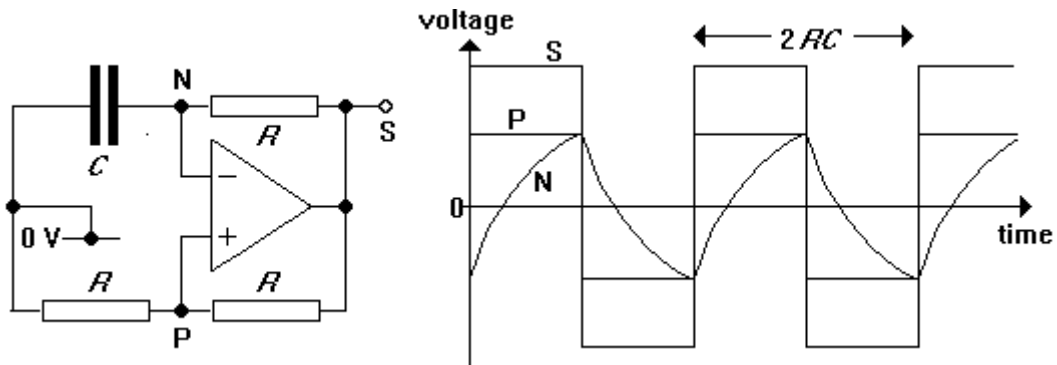
1. Assemble the circuit shown below.



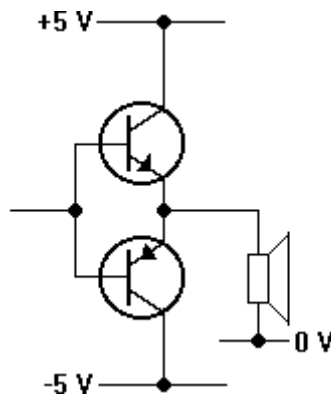
2. Measure  $V$  with a voltmeter. Set  $V$  to 1.0 V. Press the switch briefly. If all is well, the LED should glow for about 10 s.
3. Set  $V$  to 4.0 V. Use a stopwatch to measure the time for which the LED glows when the switch is briefly pressed.
4. Repeat step 3 for  $V = 2.0$  V, 1.0 V and 0.5 V in turn.
5. Use the formula  $t = \tau \ln(V_0/V)$  to calculate what the results should have been for each value of  $V$ .
6. Use the formula  $V = V_0 e^{-t/\tau}$  to calculate the value of  $V$  required for the LED to glow for exactly 60 seconds after the switch has been released. Set  $V$  to that value and measure the time for which the LED actually glows.

### A relaxation oscillator

1. Design a 500 Hz relaxation oscillator which employs an op-amp and a 100 nF capacitor. The circuit diagram is shown below.



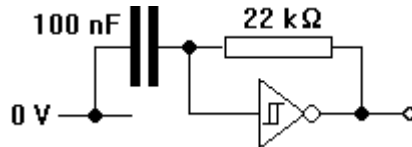
2. Assemble the oscillator. Use a CRO to measure its frequency. Study the waveforms at the plus and minus inputs of the op-amp.
3. By trial and error, determine the highest frequency at which your oscillator will work.
4. Replace the negative feedback resistor with an LDR. Your oscillator should now have a frequency which depends on the amount of light which hits the LDR. Add a push-pull follower and a speaker as shown below.



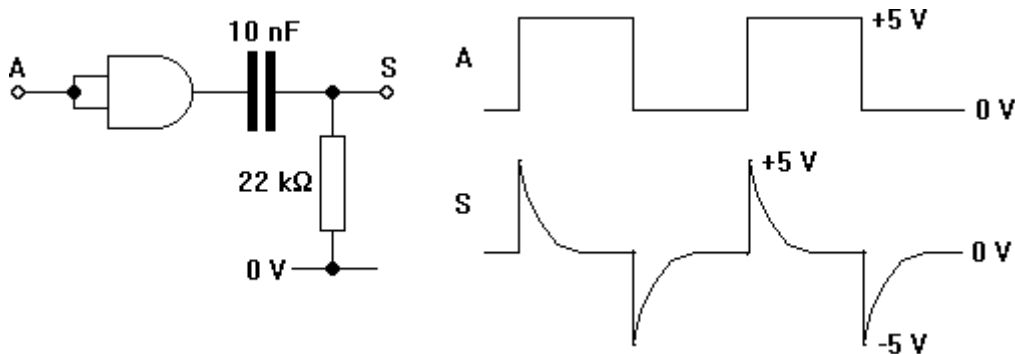
## Designing a falling-edge-to-pulse converter

You are going to design a circuit which produces a single 50  $\mu\text{s}$  pulse each time a falling-edge enters it.

1. Assemble the relaxation oscillator shown below. Run the 40106 Schmitt trigger inverter off supply rails at +5 V and 0 V.



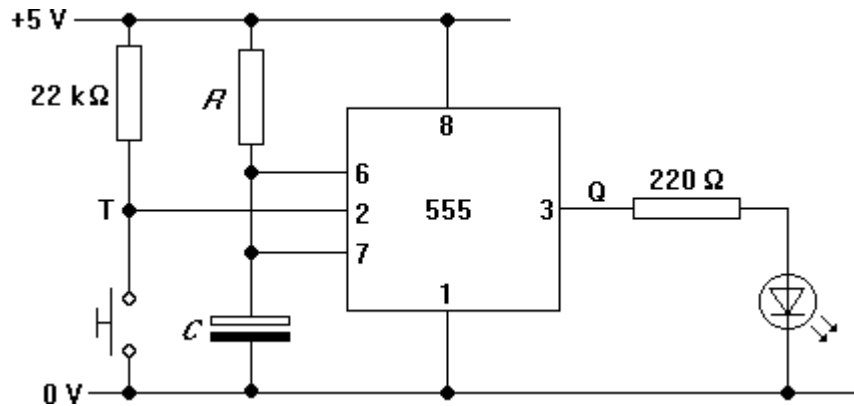
2. Use a CRO to verify that the oscillator feeds out a square wave with a frequency of about 1 kHz.
3. Assemble the circuit shown below. Connect A to the output of the oscillator and S to the second input of the CRO. Verify that the waveforms at A and S are as shown below.



4. Connect both inputs of an AND gate to S and look at its output with the CRO. Verify that it produces a single 0.15 ms pulse at every rising edge at A.
5. Adapt the circuit so that it produces a 50  $\mu\text{s}$  pulse on each falling edge at A.

**The 555 timer**

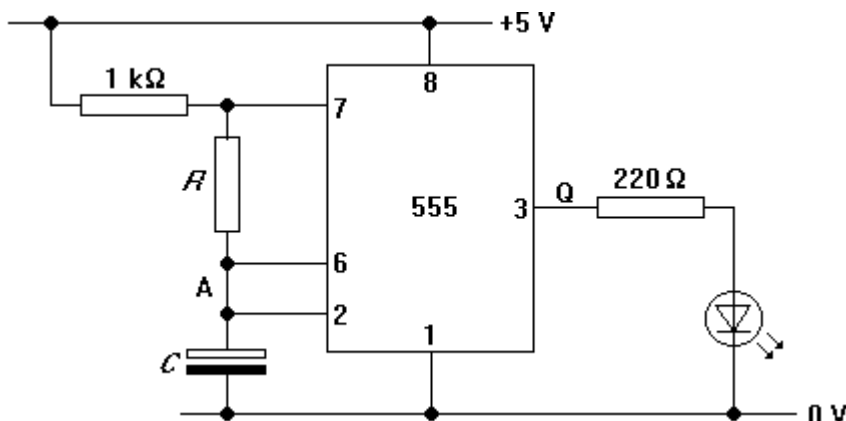
1. Assemble the circuit shown below. It employs a 555 timer i.c. as a monostable. Have  $R = 100\text{ k}\Omega$  and  $C = 100\text{ }\mu\text{F}$  to start with.



2. If all is well, the LED should glow for about 10 s when the switch is briefly pressed. Use voltmeters to find out what happens to the voltages at T and Q when the system is triggered.
3. For each of the values of the time constant  $RC$  shown in the table, measure the time  $T$  for which the LED glows after the switch is pressed. Is  $T = 1.1RC$ ?

$R$ in $\text{k}\Omega$	$C$ in $\mu\text{F}$	$T$ in s
220	10	
470	10	
100	100	
220	100	

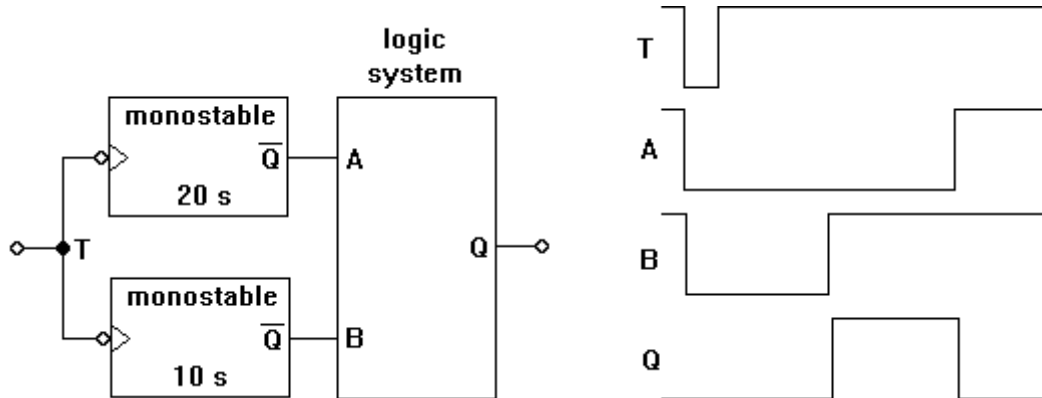
4. Now rearrange the components to make the 555 timer into an astable oscillator, as shown below. Have  $R = 220\text{ k}\Omega$  and  $C = 10\text{ }\mu\text{F}$  to start with. If all is well, the output Q should oscillate with a period of about 3 s.



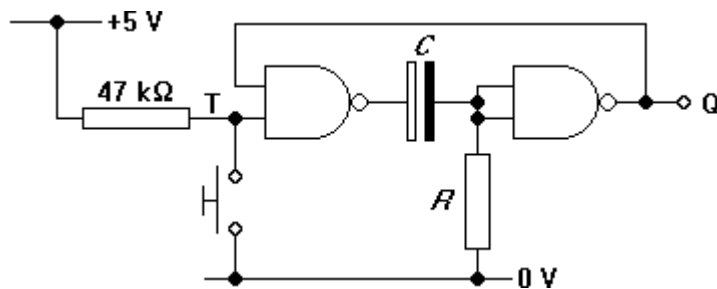
5. Measure the period  $T$  for a range of different values of  $R$  and  $C$ . How well does the formula  $T = 1.4RC$  predict the values for the period? How small can you make the value of  $R$  before the formula doesn't work?

### Delayed pulse monostable

It is often useful to be able to produce a short pulse at a fixed time **after** a system has been triggered. You are going to find one way in which it can be done. The block diagram and timing diagram is shown below.



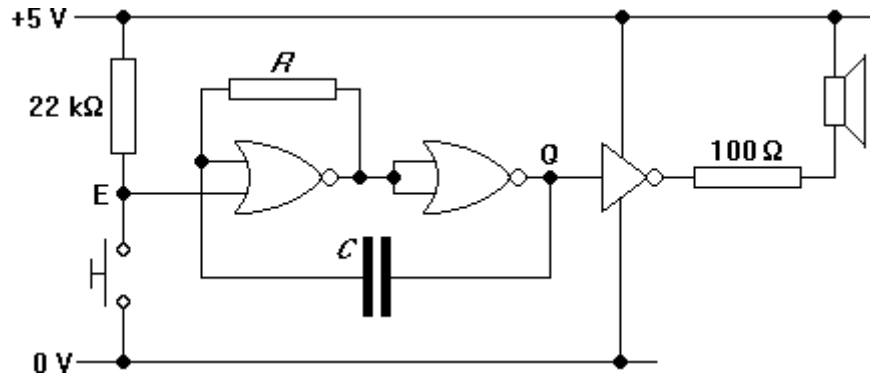
1. Assemble a monostable whose output decreases for 10 s each time that its input decreases. Use the circuit shown below:  $T = 0.7RC$  with  $R > 10 \text{ k}\Omega$ .



2. Assemble another monostable which has a pulse length of 20 s. Trigger it from the same switch as the other monostable.
3. Design a suitable logic system using NAND gates. Assemble it and test that it has the correct behaviour **before** connecting it to the outputs of the monostables.
4. Test the whole system. The LED should come on ten seconds after the switch has been pressed, and remain glowing for the next ten seconds.

### Enabled oscillators

Unlike most oscillators, the one shown below has an input which can be used to turn it on and off. You are going to make interesting noises by using one oscillator to turn another one on and off.



1. Assemble the circuit with a 4001 NOR gate i.c. and a 2004 driver i.c. Use one gate from the top half of the i.c. and another from the bottom half. Have  $C = 100 \text{ nF}$  and  $R = 10 \text{ k}\Omega$ . If all is well, the speaker should make a noise whenever the switch is pressed.
2. Use a CRO to study the outputs and inputs of the NOR gates when the system is oscillating. Does the period  $T$  of the square wave at  $Q$  obey the formula  $T = 1.6RC$ ?
3. Measure the period  $T$  for the values of  $R$  and  $C$  shown in the table. How well do they agree with the rule  $T = 1.6RC$ ?

$R/\text{k}\Omega$	$C/\text{nF}$	$T/\text{ms}$	$1.6RC/\text{ms}$
10	100		
22	100		
47	100		
47	10		
22	10		

4. Construct a second oscillator with a period of 1 s. You can make a high value unpolarised capacitor from polarised ones as shown below. Test its behaviour with a pull-down switch and the CRO.



5. Now use the output of the slow oscillator to turn the fast oscillator on and off. Speed up the frequency of the slow oscillator (by changing its component values) until the sound emitted by the speaker is interesting.