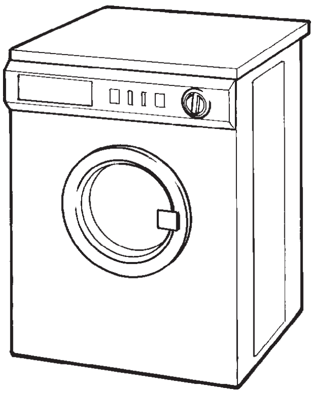
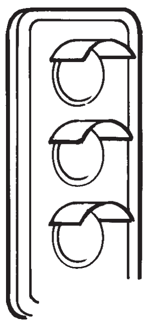
DESIGNING AND MAKING AN ELECTRONIC SEQUENCER

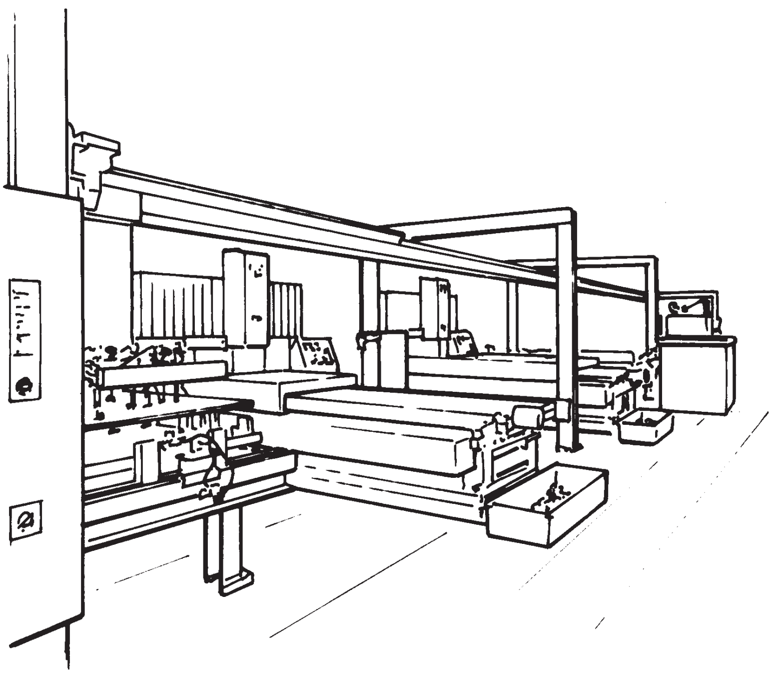
Very often an electronic system is used to perform certain operations in a specific order. One operation is completed before the next begins. Such a system is referred to as a sequential system.

Everyday examples of sequential electronic systems include: an automatic washing machine; traffic lights and disco rope lights.





Sequential systems are also in very common use in the manufacturing industry. Complex sequential systems often operate under the control of a dedicated microprocessor or a computer.



The Decade Counter

One of the simplest ways of realising a sequential electronic system is by means of an integrated circuit referred to as a decade counter.

The decade counter is essentially a 10-point electronic stepper circuit under the control of a clock. On the arrival of a clock pulse the counter advances one step. At any given time only one of the outputs is high, the other nine outputs remaining low.

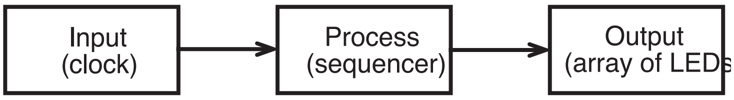
Each output goes high in sequence under the control of the clock.

Design Brief

Design and make a simple electronic sequencer that can be configured to operate an array of LEDs to produce several different visual effects.

Designing the System

The block diagram for the system will be as shown below



The input block will be required to produce clock pulses and will consist of a pulse generator.

The process block will be an electronic sequencer.

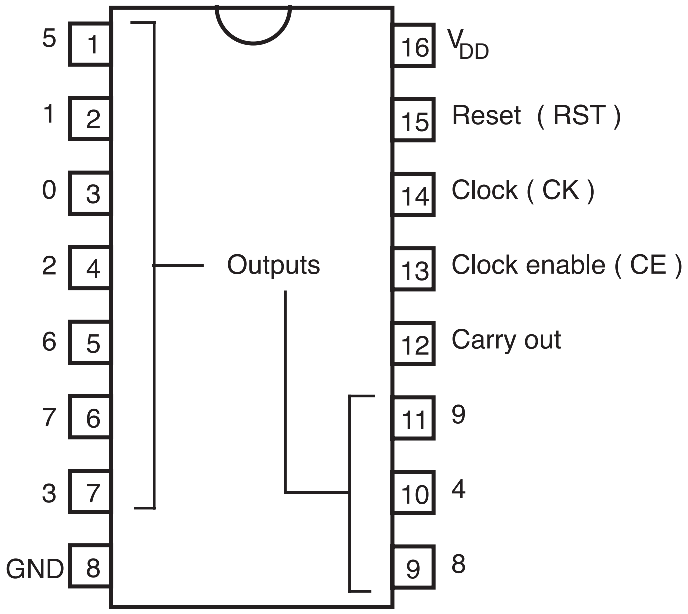
The output block will be an array of LEDs that can easily be modified to produce different visual effects.

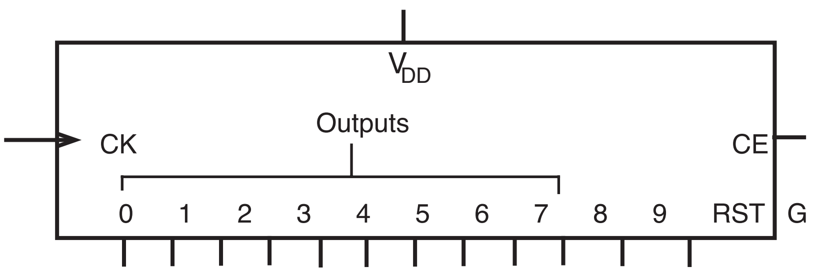
DESIGN CONSTRAINTS

Since the design brief requires a simple sequencer, a microprocessor based solution is not feasible. A simple single chip solution would be to use a decade counter for the processing block.

PROCESS BLOCK

The decade counter is available in the CMOS 4017B. The pin out and schematic diagrams of the 4017 are shown below.





For any given application the outputs are shown in the most convenient order. The carry out output is not required and is left out of the schematic diagram.

We need to be aware of the following information which has been extracted from a 4017 data sheet.

1. The counter is positive edge triggered.

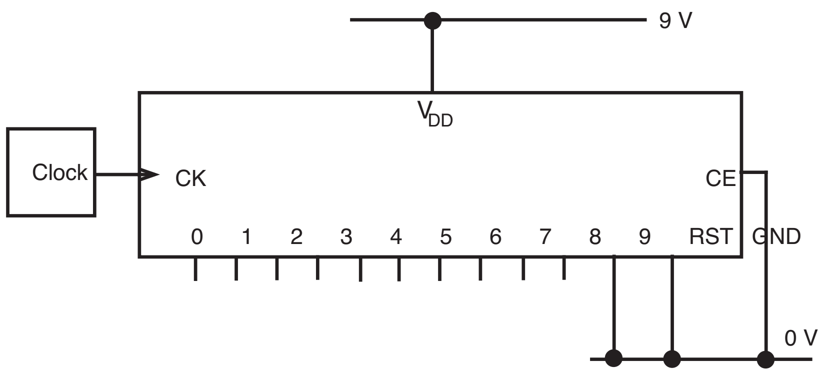
2. The reset pin (RST) is held low during sequencing. Taking RST high, set output 0 high and the other nine output low.

3. The clock enable pin (CE) is held low during sequencing. If CE is taken high the sequence will freeze at its 'present' position and will continue to sequence when CE is returned to low.

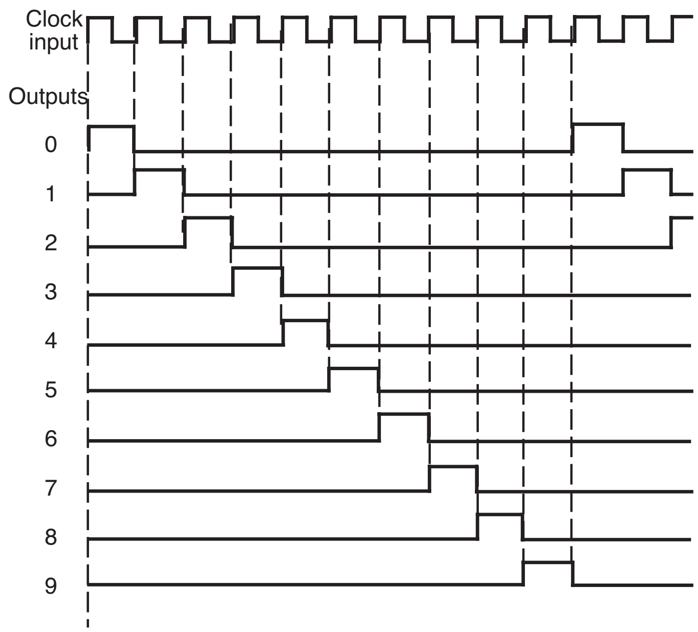
4. A sequence may be shortened by connecting the first unwanted output to the reset pin.

5. The output of the 4017 is internally current limited. With a 9V power supply the maximum current that can be drawn from the 4017 is approximately 15 to 20 mA.

The following circuit connections will cause the 4017 to continually sequence with each output being held high in turn for one whole cycle of the clock signal.

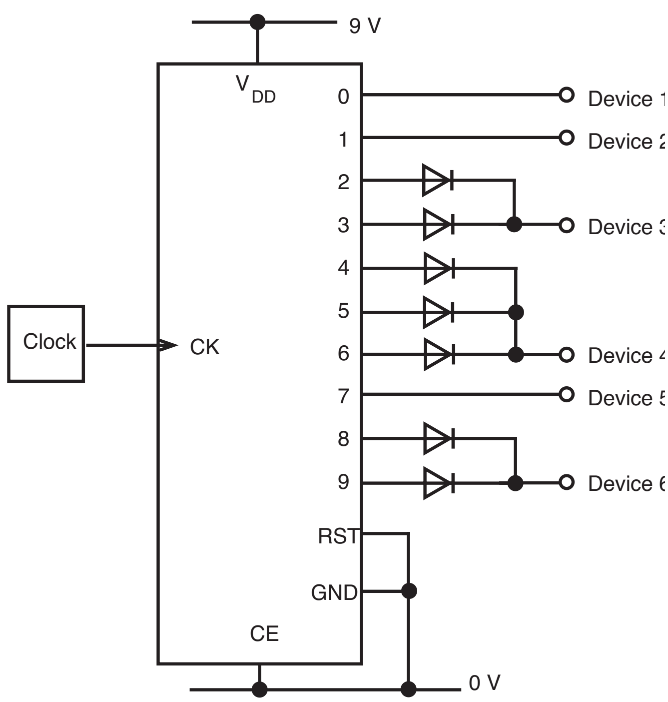


The waveform timing diagram showing how each output goes high in turn under the control of the clock is shown below.

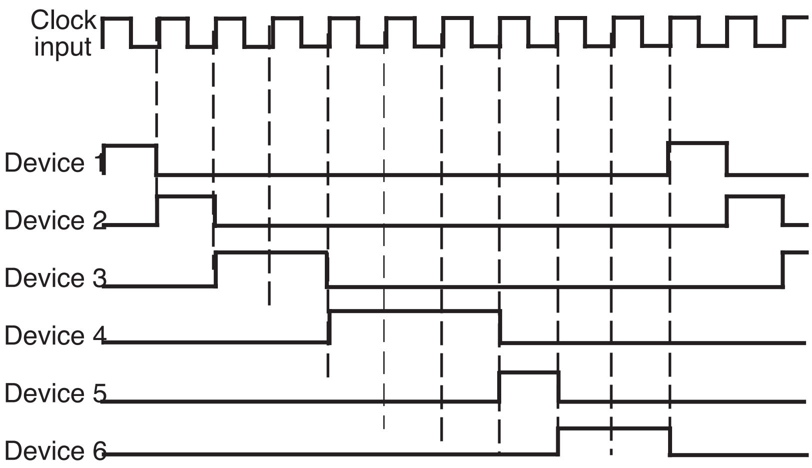


UNEQUAL SEQUENCE TIMING

Quite often it is necessary for some of the outputs of a sequencer to remain high for longer than others. This can be achieved by feeding the signal from several of the 4017 outputs to a single output device via diodes In the following example six output devices are activated for different lengths of time.



The waveform timing diagram for this system would be



Devices 1, 2 and 5	will be on for 1 clock cycle.
Devices 3 and 6	will be on for 2 clock cycles.
Devices 4	will be on for 3 clock cycles.

The purpose of the diodes in the circuit is to isolate the signals from each ‘shared’ output from one another. This prevents the signals interfering with one another.

OUTPUT BLOCK

The current available from each output of a 4017 IC is more than adequate for driving LED arrays. We can therefore connect LEDs directly to the output of a 4017 IC.

The design brief requires provision for several different visual effects. We shall now consider two types of output display the first will consist of a light chaser display and the second will be an electronic dice.

LIGHT CHASER CIRCUIT

A light chaser consists of an array of LEDs (or lamps) that are arranged to be driven such that individual LEDs turn on and off in a predermined and continually repeating pattern. This sequence creates an optical illusion of a ripple or movement of light. An example of such an illusion can be seen in a disco rope light.

Individual LEDs may be used or ready assembled arrays of LEDs are available. The 10 LED bargraph LED display consisting of 10 LEDs housed in a 20 pin DIL package is particularly useful for demonstrating chaser circuit.

Although the 4017 outputs are limited to less than 20 mA, a high efficiency or Super Red LED will illuminate to an adequate light level with a current of less than 5 mA. If these types of LEDs are used, a 680Ω resistor can be connected between the LED array and OV, thus preserving the life of the battery. With ordinary LEDs the 680Ω resistor should be replaced with a wire link or a 270Ω resistor.

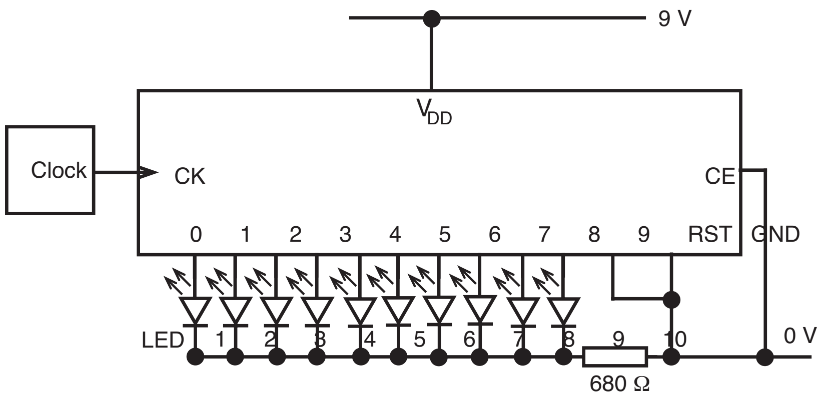
We shall now consider five light chaser circuit configurations that can drive an array of LEDs.

For each of the chaser circuits shown the best effect is obtained with a clock frequency of approximately 20 Hz.

CIRCUIT 1

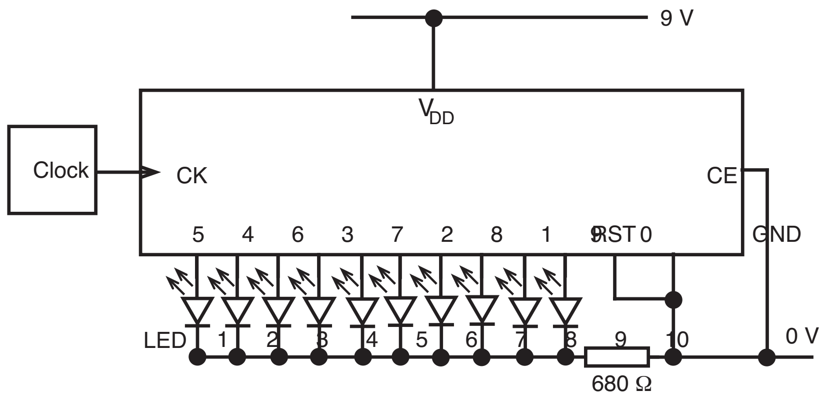
The following configuration will produce the visual effect of a spot of light repeatedly sweeping from left to right if the LEDs are arranged in a straight line. If the LEDs are arranged in a circle the circle will seem to rotate.

If fewer than ten LEDs are required in the sequence then the first unused output is taken to the reset pin and all the other unused outputs are left unconnected. The sequence would be similar to the original sequence except that the number of steps in the sequence is reduced.



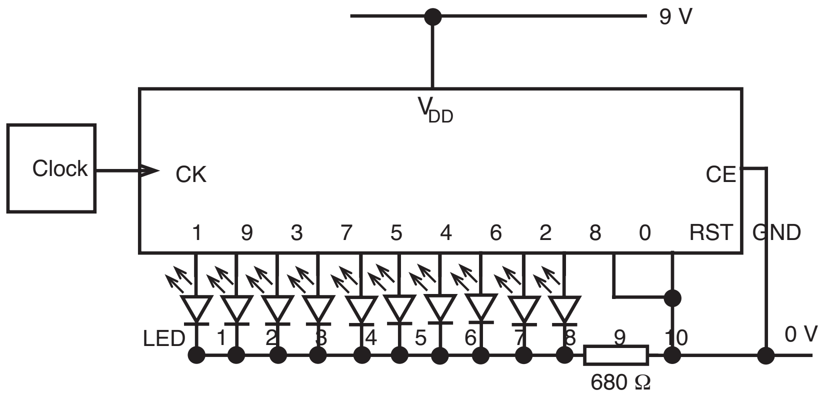
CIRCUIT 2

This configuration produces the visual effect of a spot of light sweeping from right to left then from left to right repeatedly.



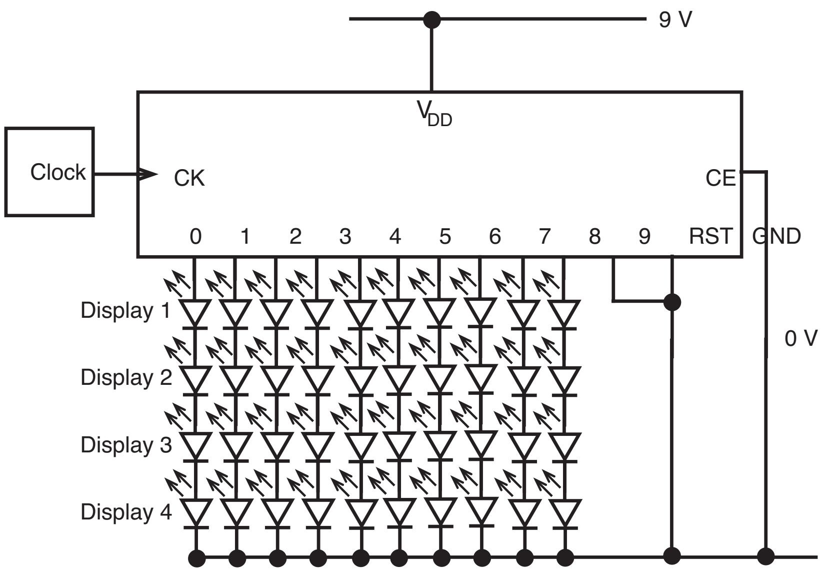
CIRCUIT 3

This configuration produces the effect of two spots of light continously moving towards each other then moving away from each other.



Increasing the Number of LEDs

On a 9V power supply each 4017 output can drive up to four LEDs connected in series. Circuit 1 is redrawn below to show the necessary modifications.

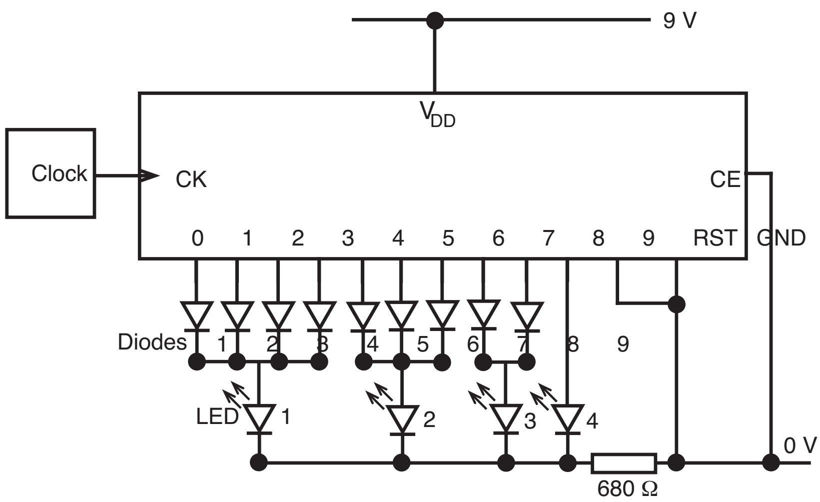


The use of bargraph LEDs would greatly simplify the wiring of the 40 LED array.

It is left to your imagination to consider the possible effects that could be obtained. For example the first LED on display 1 could be connected to the last LED on display 2 and so on.

CIRCUIT 4

This configuration makes use of unequal sequence steps. It produces the effect of a spot of light accelerating as it moves from left to right.

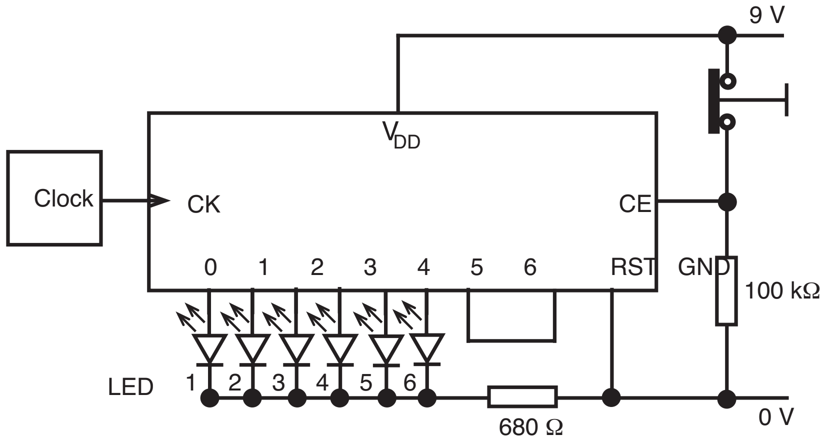


ELECTRONIC DICE

This would require six LEDs labelled with the numbers 1 to 6 connected to outputs 0 to 5 respectively. Then first 'unwanted' output (output 6) is connected to the reset pin.

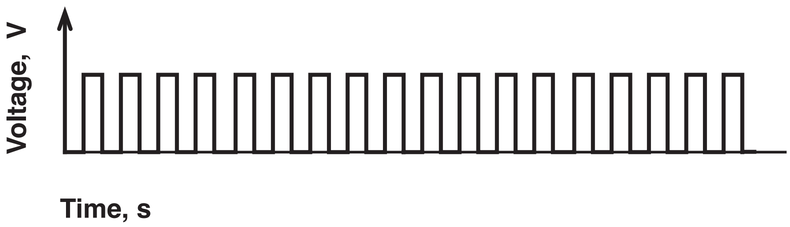
The dice will display the last number thrown until a normally closed push switch S is pressed. While the switch is being pressed the 6 LEDs will come on in sequence. To prevent contestants cheating, a fast clock frequency of about 4kHz could be used. This means that each of the six numbers is being illuminated over 600 times for each second the switch is held down. Once the switch is held down the clock enable pin (CE) is taken low and counting commences. On releasing the switch, the clock enable pin is taken high and the sequence will freeze, randomly choosing a score on the dice.

The circuit for the electronic dice is shown below.



INPUT BLOCK

An input block is required that produces a regular series of pulses as shown in the following waveform.



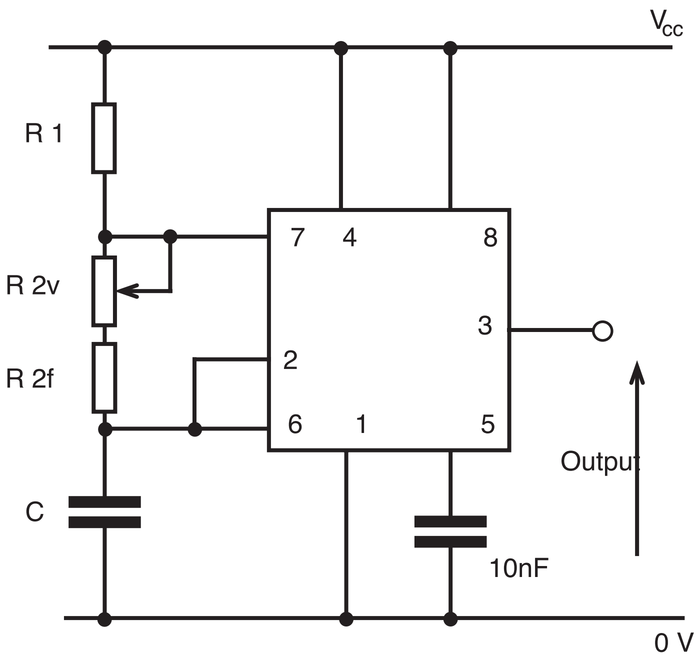
A circuit that provides this square wave output is known as an astable. There are many different ways of making an astable circuit, all of which involve the charging and discharging of a capacitor through a resistor.

The astable will provide clock pulses to allow the 4017 IC to sequence at the required frequency. The suggested frequency for the light chaser outputs was approximately 20 Hz and for the electronic dice was approximately 4kHz. For other applications a frequency of 1 cycle every several seconds might be appropriate which would require quite a large electrolytic capacitor to be used. It is for this reason that the popular 555 timer IC is to be used.

In 555 timer circuits the timing capacitor always has one end connected to the 0V rail. Any current applied to the capacitor flows towards the 0V rail allowing us to use a large electrolytic capacitor in the circuit. (See study File 6).

To reduce the power consumption the CMOS version of the timer i.e. the 7555, will be used.

The circuit diagram for the astable is shown below.

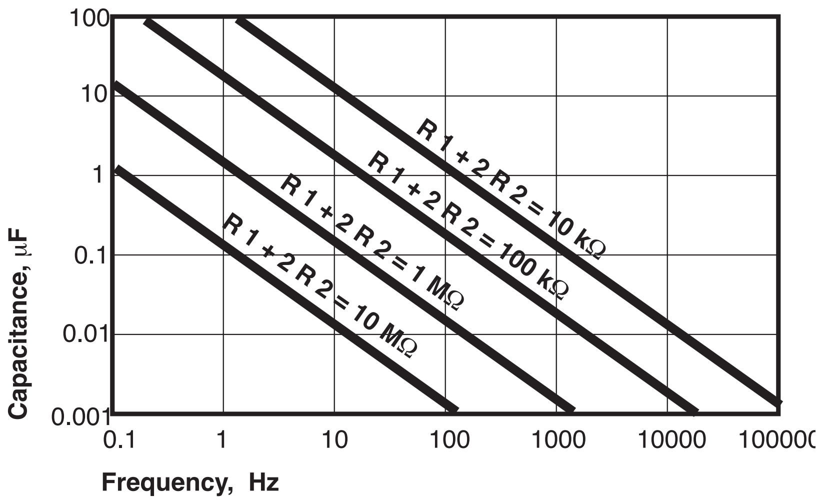


CHOOSING COMPONENT VALUES

We will choose the minimum allowable value for R1 which is 1kΩ.

R2 consists of a fixed resistor R2f and a variable resistor R2V. Since the minimum allowable value of R2 is also 1kΩ then R2f should be 1kΩ.

R2 and C can be chosen using the following graph, more detail of which are provided in Study File 6.



The frequency of the astable should be variable between 0.1Hz and 4kHz approximately.

The lowest frequency required is 0.1Hz. By looking at the graph you should notice that this frequency can be obtained with a 10 µF capacitor and (R1 + 2R2) approximately equal to 1MΩ.

It is left to you to confirm that with C=10 μF; R1 = 1kΩ; R2f = 1kΩ and R2v = 1MΩ, then frequencies in the range 0.072 Hz to 48 Hz are available by varying R2v over its full range.

The highest frequency required is 4kHz. By looking at the graph you should notice that this frequency can be obtained with a 0.1 μF capacitor and (R1 + 2R2) slightly less than 10 kΩ.

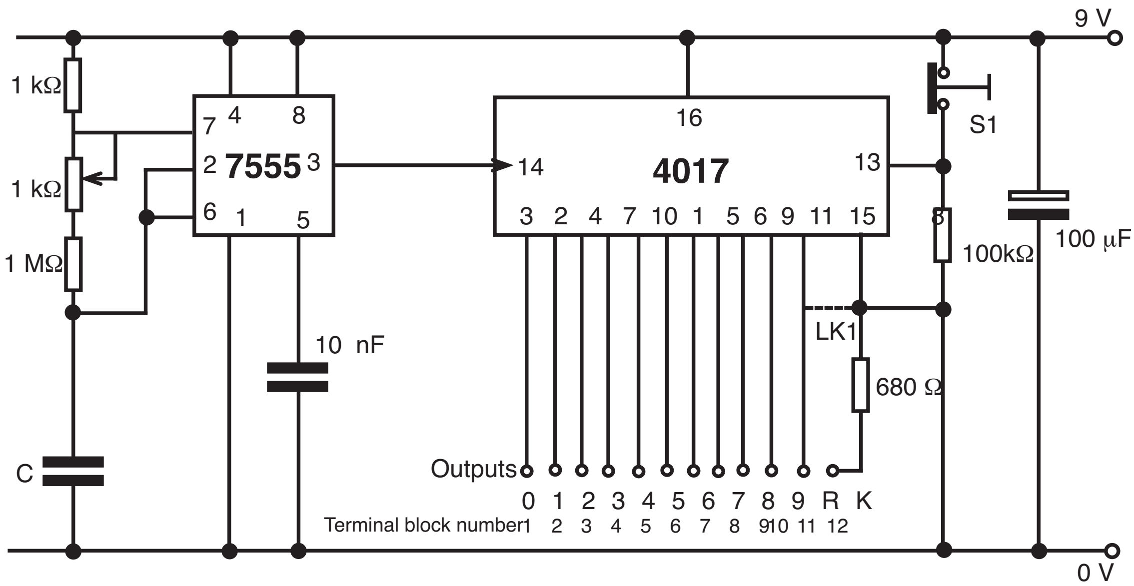
It is again left to you to confirm that with C = 0.1 μF; R1 = 1kΩ R2f = 1kΩ; R2v = 1MΩ then frequencies in the range 7.2 Hz to 4.8 kHz are available by varying R2V over its full range.

PUTTING IT ALL TOGETHER

Each of the output configurations considered could quite easily be incorporated into a permanent circuit design on an individual basis but they could not all be encompassed into a single design.

The most flexible solution is to build the clock and sequencer on a single circuit board with all the necessary connection brought out to a terminal block. The LED array can then be wired to the screw terminal block to produce any required light sequence. In most applications the display would be remote from the circuit board in any case.

The circuit diagram for the system is shown below.

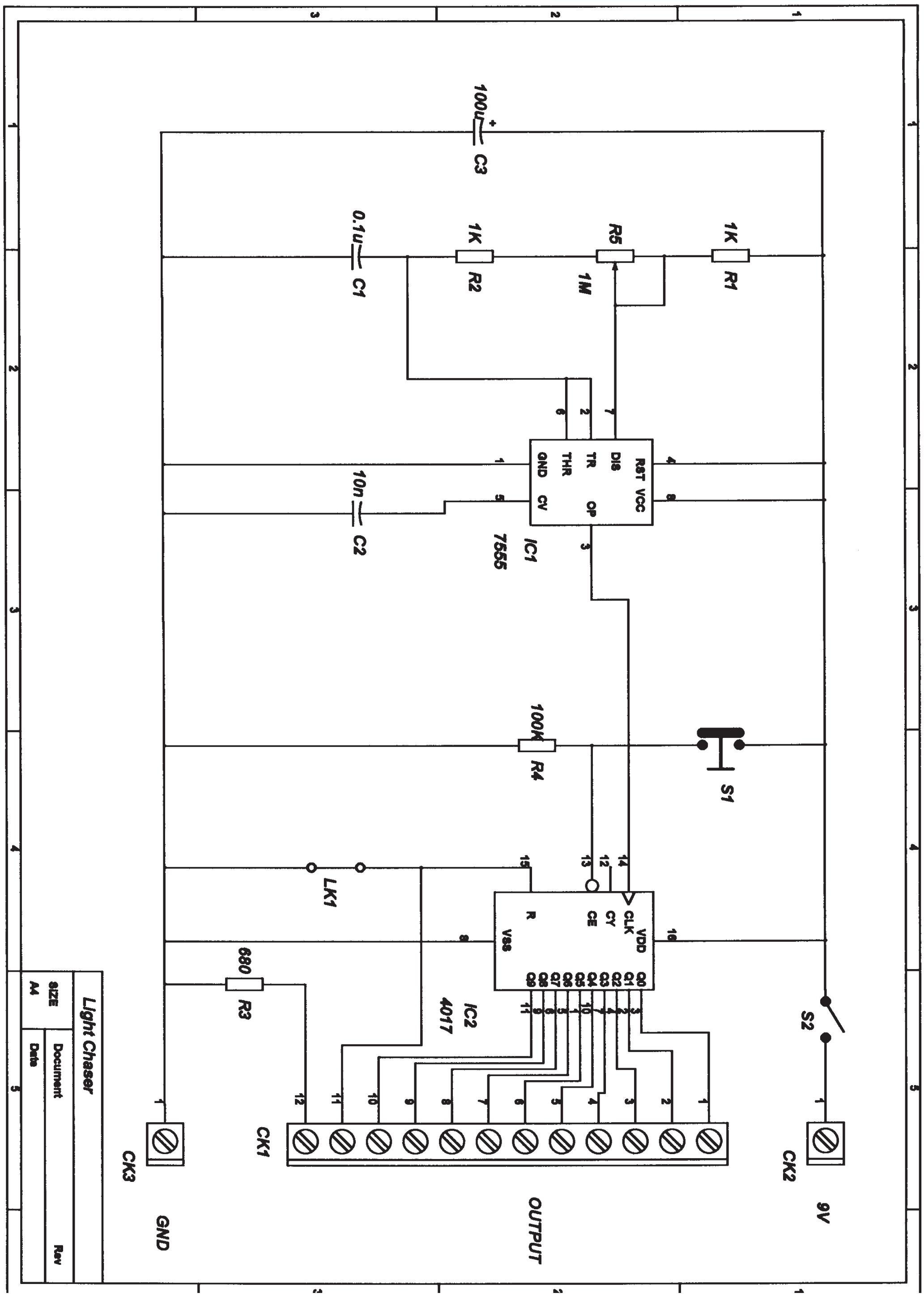


Note 1: Link LK1 has to be inserted if all ten outputs are required.

Note 2: Switch S1 and the 100kΩ resistor are required only for the electronic dice.

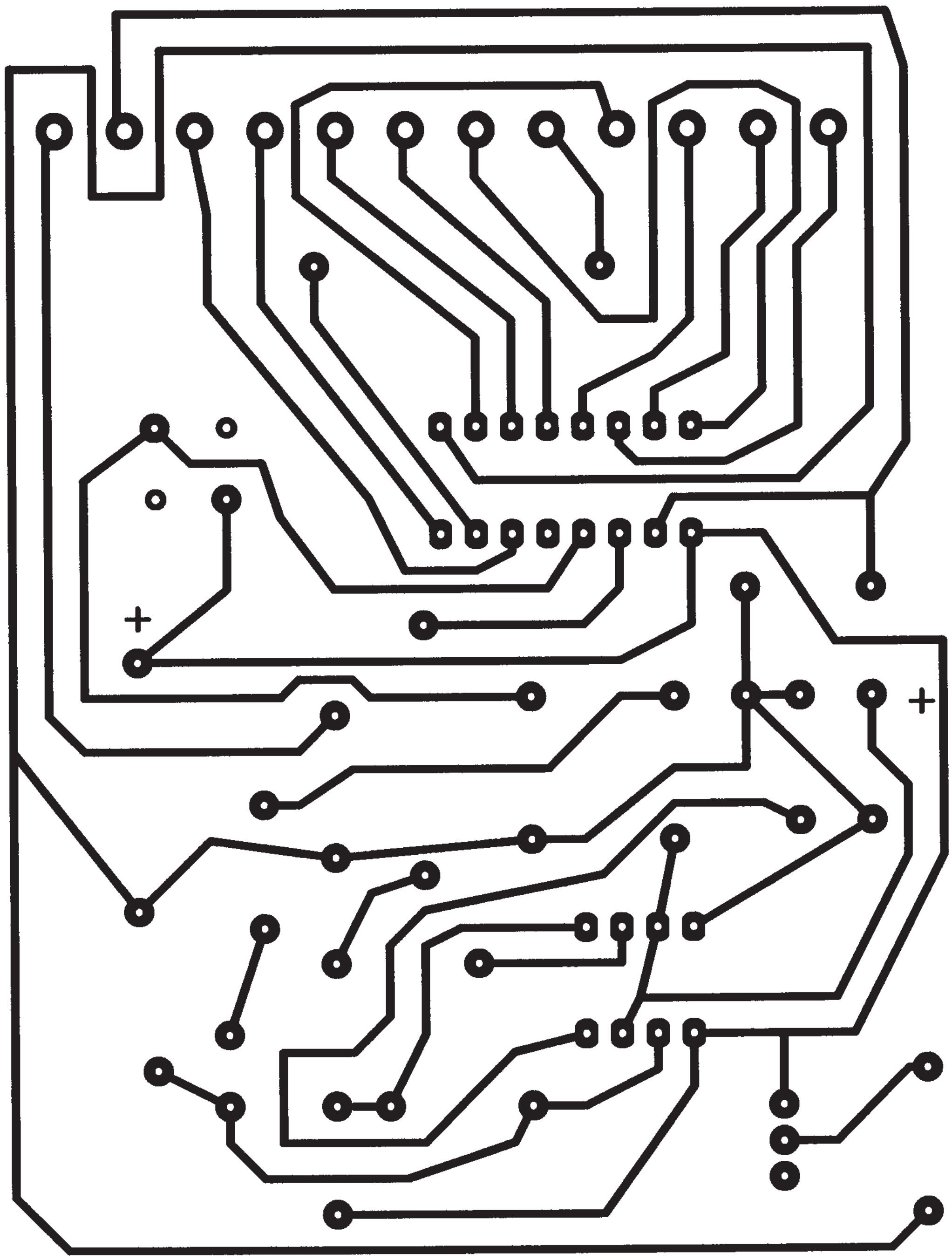
You will need to make a printed circuit board (PCB) on which to mount the components. To find out about this see Study File 8 (Making a PCB). The following four drawings have been produced on a PCB design software package. A disk is also supplied containing a file which includes all four drawings. More information about the PCB design software is given in Study File 8.

SCHEMATIC CIRCUIT DIAGRAM



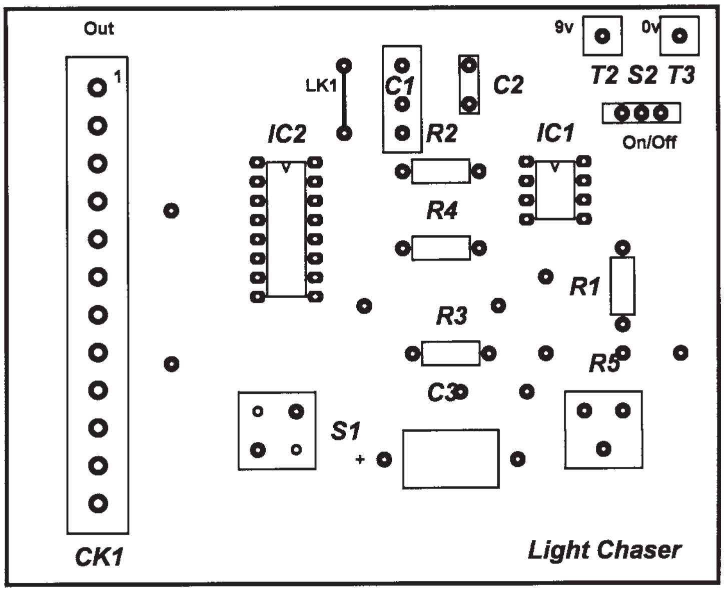
This is the circuit diagram for the complete system redrawn by the design software. The software uses the diagram to create the other three diagrams.

PCB LAYOUT DIAGRAM



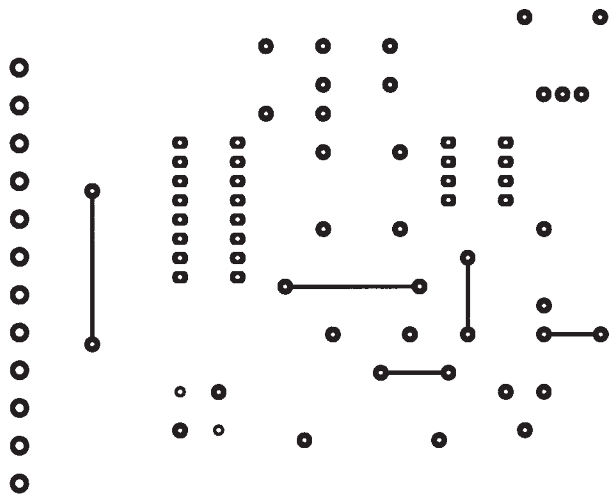
This diagram is used to create the PCB mask on an acetate sheet as described in Study File 8. The diagram is supplied twice normal size so the photocopier should be set to 50% reduction when producing the mask.

COMPONENT LAYOUT DIAGRAM



The diagram shows you where each of the components is to be mounted on the PCB.

WIRE LINK DIAGRAM



This diagram shows you where wire links have to be inserted.

It is advisable to mount all the IC socket holders first. You can then check with a multimeter set to the 200Ω range to ensure that solder has not spilt on any tracks which pass between adjacent pins.

TESTING

When you have built the circuit, you will need to test it to see if it works correctly.

Wire the LED array to the terminal block. Remember that if all ten outputs of the 4017 are to be used, link LK1 has to be inserted. (See Note 2 on the Circuit Diagram for the complete system).

If the electronic dice is required insert switch S1 and 100kΩ resistor R4 and leave out link 1. Link terminal block output 11 (4017 reset terminal) to terminal block output 7 (4017 output 6).

If the clock is set to its lowest frequency then you should see the LEDs come on one after another. If the sequence is incorrect check the wiring from the terminal block to the LED array.

If the clock is set to its highest frequency all the LEDs will appear to be on.

If the circuit does not work, follow the simple Fault Finding procedure below:

1. Check that no tracks or pads are bridged or broken. Repair if necessary (see Study File 8).

2. Check that all solder joints are good.

3. Check that all components are mounted correctly. Pay particular attention to the ICs. It is quite easy to plug them in the wrong way around.

4. If all this fails try changing the ICs.

Evaluating the Sequencer

There are a number of things you need to consider when evaluating the system.

1. How well does it work?

   Is the range of frequencies available from the clock adequate?

   Is the sequence being displayed clearly visible?

2. Will it work in the situation for which it was designed?

   Can the outputs be easily rearranged to allow you to change the sequence.

3. Are the interconnections between the output terminal block and the LED array robust enough?

   Can you improve the method of interconnection?