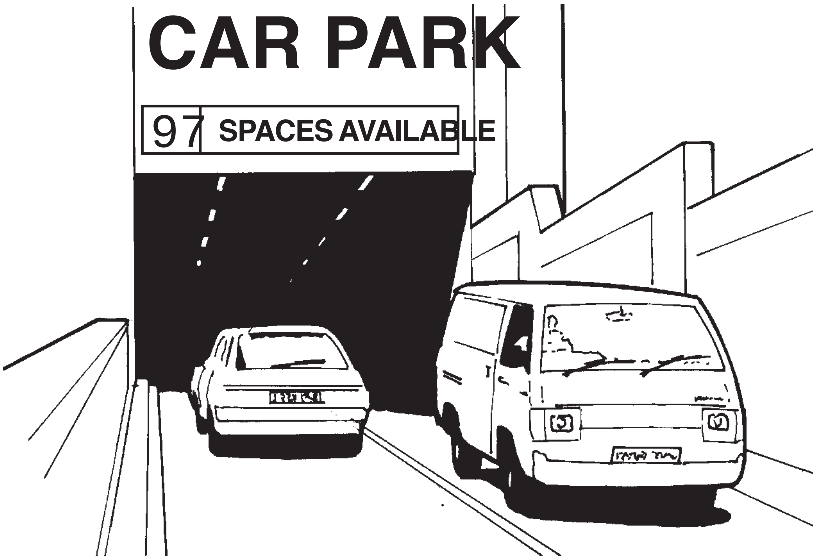
DESIGNING AND MAKING AN ELECTRONIC COUNT AND DISPLAY SYSTEM

There are numerous situations where the occurrence of an event has to be counted. For example, the number of car parking spaces available in a car park or the number of boxes passing along a conveyor belt, or the number of people entering a lift.



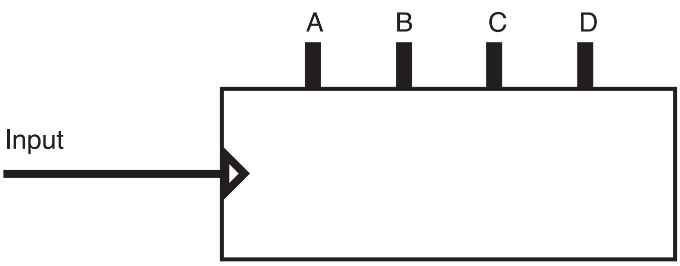
COUNTING IN BINARY

We count using the decimal number system which makes use of the ten digits 0 to 9. Electronic counters count in the binary number system which consists of the two digits 0 and 1. The “0” can easily be represented electronically by a low voltage level and the “1” represented by a high voltage level.

A binary digit is often referred to as a bit.

The highest number that an electronic binary counter can count up to before resetting and then repeating a count depends on the number of bits in the counter.

The schematic diagram of a single 4-bit binary counter is shown here.



The output pattern of the 4-bit binary counter is shown below:

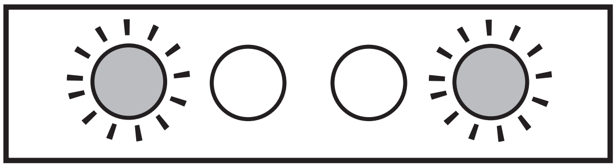
INPUT	BINARY OUTPUT			
Event No.	D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1
16	0	0	0	0

The binary digit in the 'A' column is referred to as the least significant bit (LSB).

The binary digit in the 'D' column is referred to as the most significant bit (MSB).

The events being counted by the binary counter must be converted into pulses and applied to the input of the counter each time the event occurs.

The number of events that have occurred could be displayed on four LEDS. For example, 9 events could be displayed as



This could be quite easily be interpreted as binary 1001 and converted to decimal 9.

If we apply this principle to the spaces available in a car park, a 7-bit counter could be used to count up to 127 and the sign which previously read

would now read

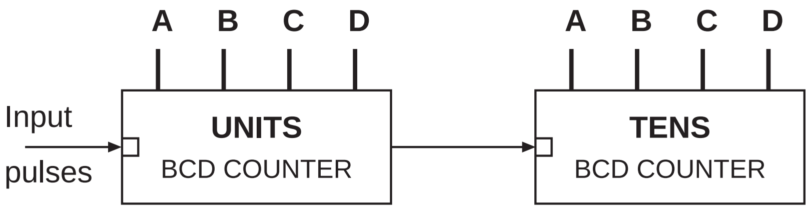
which would be almost impossible for most drivers to convert to ninety seven in decimal.

The only practical solution is to display the count as a decimal number by processing the output of the binary counter. This can be done in two steps.

COUNTING IN BINARY CODED DECIMAL

The first step is to assign a 4-bit counter to each of the decimal digits to be displayed and restrict the highest count on each 4-bit counter to decimal nine (i.e. binary 1001). This type of counter is referred to as a binary coded decimal or BCD counter.

A 0 to 99 counter would have two 4-bit BCD counters connected together or 'cascaded' as follows.



The input pulses to the 'tens' counter are provided by the units counter each time the output changes from 1001 to 0000.

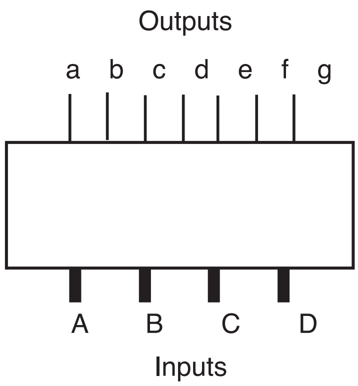
COUNTING AND DISPLAYING

The outputs from the BCD counters are still in binary form, therefore a second step is required to change or decode the output into decimal so that it can be displayed on a seven segment display.

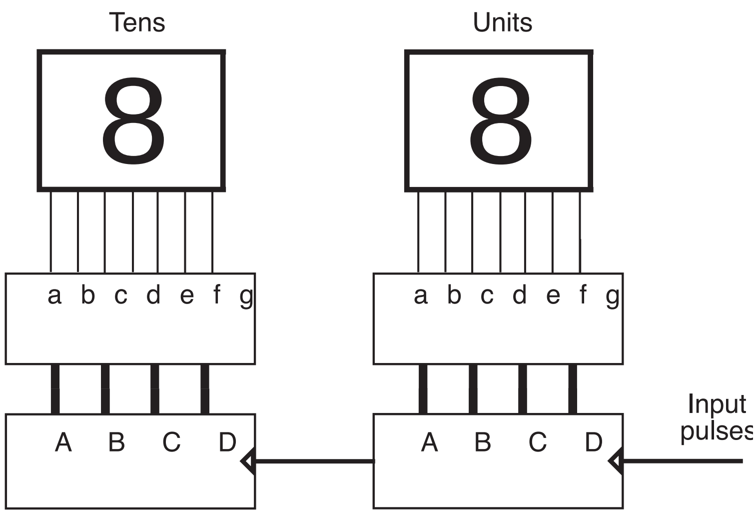
To find out about seven segment displays see Technology Study file 3.

The four outputs from each BCD counter have to be converted into seven outputs a, b, c, d, e, f and g, each capable of providing sufficient current to illuminate one segment of the seven segment display. For each of the ten possible BCD output patterns a different combination of display segments has to be illuminated. The circuitry required to do this is complex but fortunately a single integrated circuit is available and is referred to as a BCD to seven segment decoder/driver.

The schematic diagram of a seven segment decoder driver is shown below.



A 0 to 99 counter and decimal display is shown below.



CONNECTING INPUTS TO A COUNTER

The input pulses applied to a counter must rise and fall very sharply and be clearly defined, otherwise the counter may ignore the pulses completely or may interpret one pulse as several.

More often than not the input pulses to the counter will be provided by a mechanical switch being activated or a light beam being broken. The pulses provided by these inputs are unsuitable for connecting directly to a counter and have to be shaped or **conditioned** first.

To find out about signal conditioning circuits see Technology Study File 5

TYPES OF COUNTER AVAILABLE

There are numerous types of BCD counter available: up; down; up/down; positive edge triggered; negative edge triggering; combined counter/decoders etc. The choice you make will depend on the specific application you have in mind.

DESIGN BRIEF

Design and make an electronic counting system that will enable someone training in a gymnasium to register and display counts up to 99.

The counter should be capable of responding to several types of input.

The counter should be portable, resettable and use a minimum amount of electricity when powered from a 9V battery.

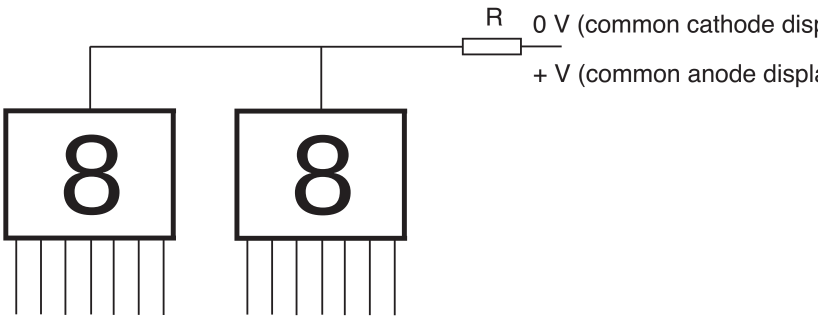
DESIGNING THE SYSTEM

OUTPUT BLOCK

The main consideration is the current requirements of the seven segment displays which are notorious for rapidly draining a battery. Normally such displays require about 10 mA to flow through each segment to be sufficiently illuminated. This would require a total current of 140 mA if all fourteen segments were illuminated simultaneously (as would be the case when 88 was being displayed).

Thankfully, there is a new generation of LED displays available referred to as Super Red, which will give approximately the same illumination as a normal LED display with only one tenth of current consumption.

Super Red LEDs also have the advantage over normal LEDs in that the illumination is more constant over the current range 0.5 to 5 mA. This property will enable us to use a single current limiting resistor instead of using a limiting resistor for each segment of the display.



A 470Ω resistor will limit the total current to less than 15 mA when connected to a new 9V battery. To prolong the battery life even further, a variable 470Ω resistor could be connected in series with the fixed resistor. The brightness of the display can then be adjusted to suit both the ambient light and/or the condition of the battery.

See Technology Study File 3 to find out more about seven segment displays and how to limit the current through them.

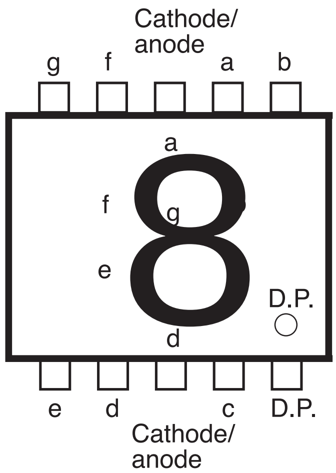
Choosing a Display

Seven segment displays can be purchased in several sizes and with different pin arrangements. Displays with the pins arranged along the sides can be bought in heights 0.3"; 0.4" and 0.43" and are typically £1.40 for a Super Red type.

Displays with the pins arranged along the top and bottom of the display are available in 0.5" and 0.56" heights and are typically £1.60 for a Super Red type.

The main advantage of the latter type is that the pin arrangement simplifies the layout design of a printed circuit board as well as being slightly better value for money.
We will, therefore, use 0.56" Super Red seven segment displays

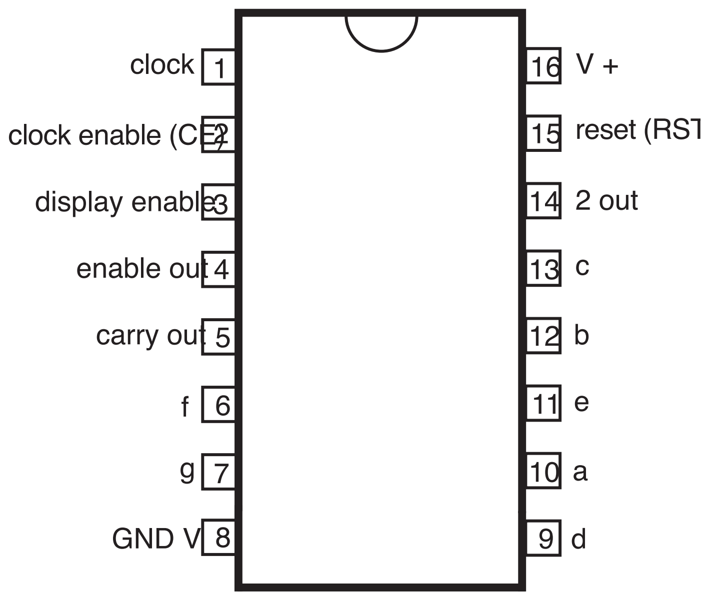
Our choice of common cathode or common anode displays will have to be delayed until we have chosen our processing block.



PROCESSING BLOCK

The fact that we have chosen a seven segment display requiring only a few milliamp to illuminate a segment has made our choice of counter and decoder quite easy to make. A CM0S 4026 is a combined counter/decoder integrated circuit with a limited drive capability. The maximum drive capability of 5mA per segment is more than adequate for our chosen display. The obvious advantage of using this IC is that it makes our circuit less complex by saving two ICs.

The CMOS 4026 IC is available in a 16 pin DIL package as shown in the pin out diagram here.



We need to be aware of the following information which has been extracted from a 4026 data sheet.

1. The outputs are designed to work with common cathode displays.

2. The counter is positive edge triggered.

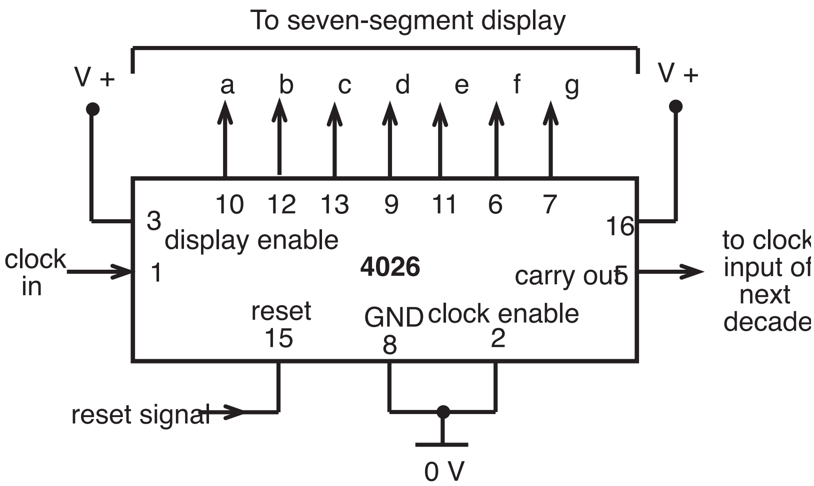
3. The reset pin (RST) is held low during counting and the counter resets when RST is taken high.

4. The counter has some advanced features that are not required for our circuit, therefore the clock enable (CE) pin is connected to 0V and the display enable is connected to +9V.

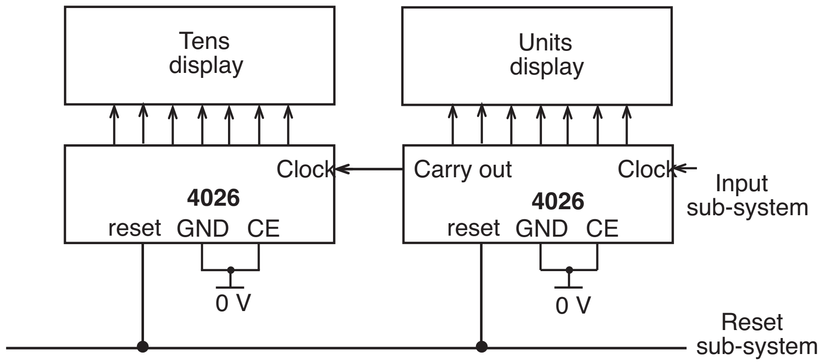
5. The clock input of the units counter is connected to the input of the system and the clock of the tens counter is connected to the carry out of the units counter. The 2 out and enable out outputs are not required and are left disconnected.

6. The clock must be noiseless and have a single high to low transition per desired count. Clock rise and fall times must be less than 5 microseconds.

Bearing in mind the above information we can now draw a schematic diagram to indicate where each pin of the 4026 has to be connected to.



For a 2 digit display system the two 4026's are interconnected as follows. (The connections to v+ have been omitted for clarity.)



INPUT BLOCK

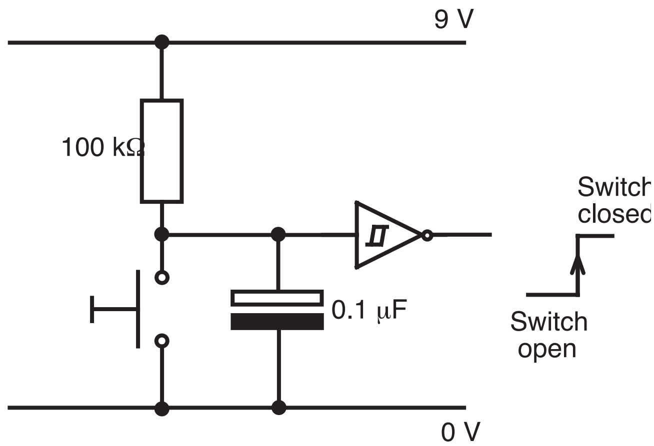
The input sub-system has to produce a single noise-free rising-edge pulse with a very fast rise time. This pulse is then fed into the clock input of the 'units' 4026 counter.

The design brief requires the counter to count an event automatically when someone is training in a gym. Two possible ways of counting such events are either by breaking a light beam or by operating a mechanical switch.

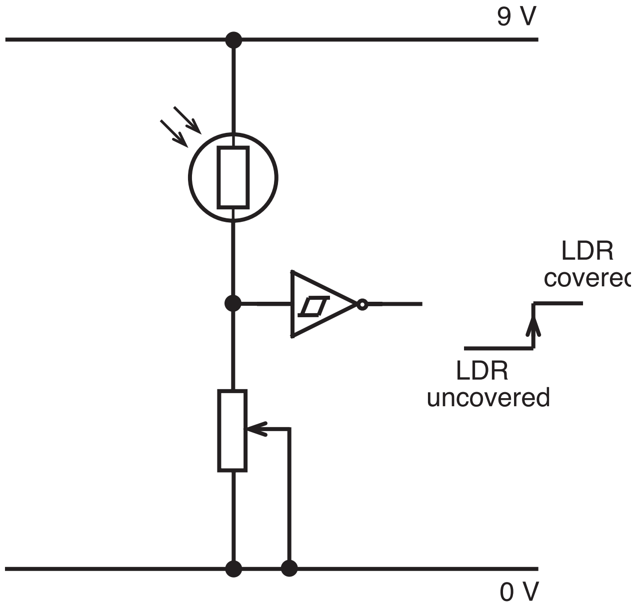
If you refer to Study File 5 you will learn that the signals produced by light sensors and mechanical switches has to be processed using a Schmitt inverter before connecting to the input of a counting system.

The following input sub-systems will provide a signal suitable for connecting to the clock input of a 4026 counter.

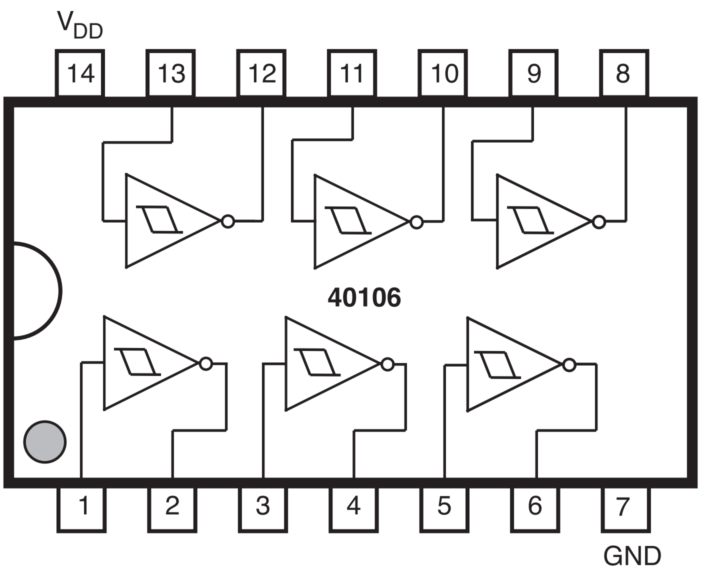
(i) Mechanical switch input sub-system.



(ii) Light sensing input sub-system.



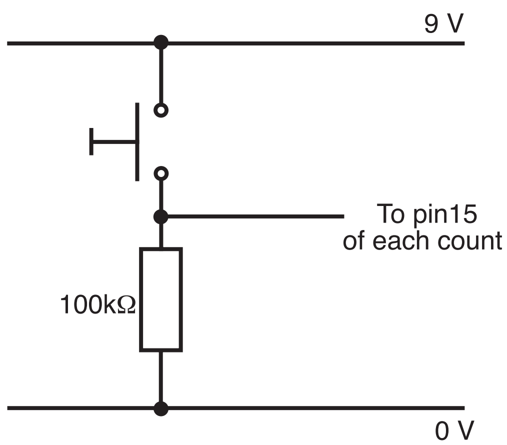
A CMOS 40106 Schmitt inverter is available in a 14 pin DIL package. The pinout diagram for a 40106 is shown below.



THE RESET INPUT

Both displays need to be reset simultaneously with the press of a single switch. From the data sheet information we know that the reset pin has to be held low during counting and will reset the counter to zero if momentarily taken high.

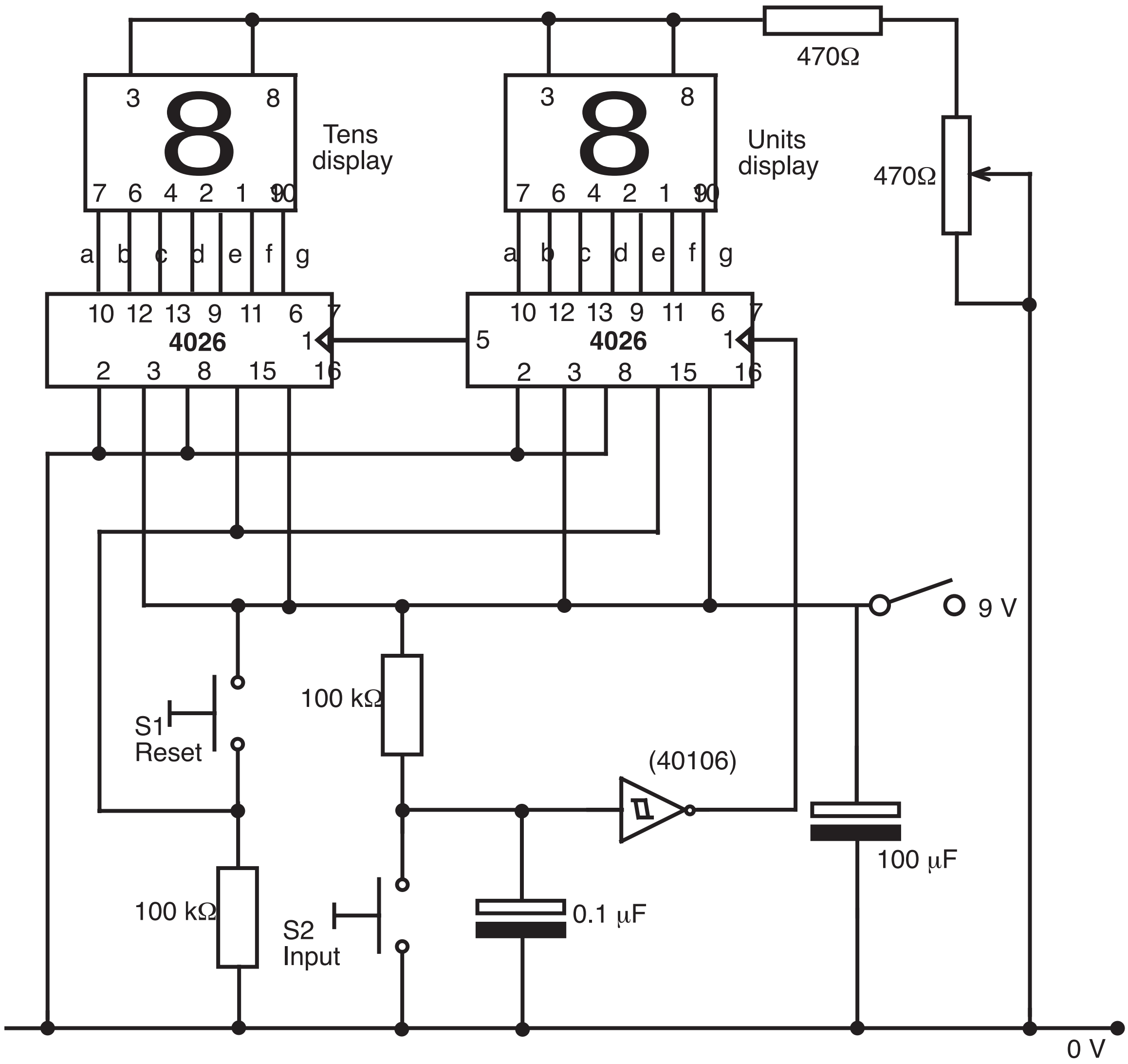
This function can be provided with a push to make switch and a pull down resistor as shown below.



See Study File 5 for more information about pull down resistors and Study Files 1 and 2 for information about LDRs and switches.

PUTTING IT ALL TOGETHER

The circuit diagram for the complete system using a mechanical switch input is shown below.



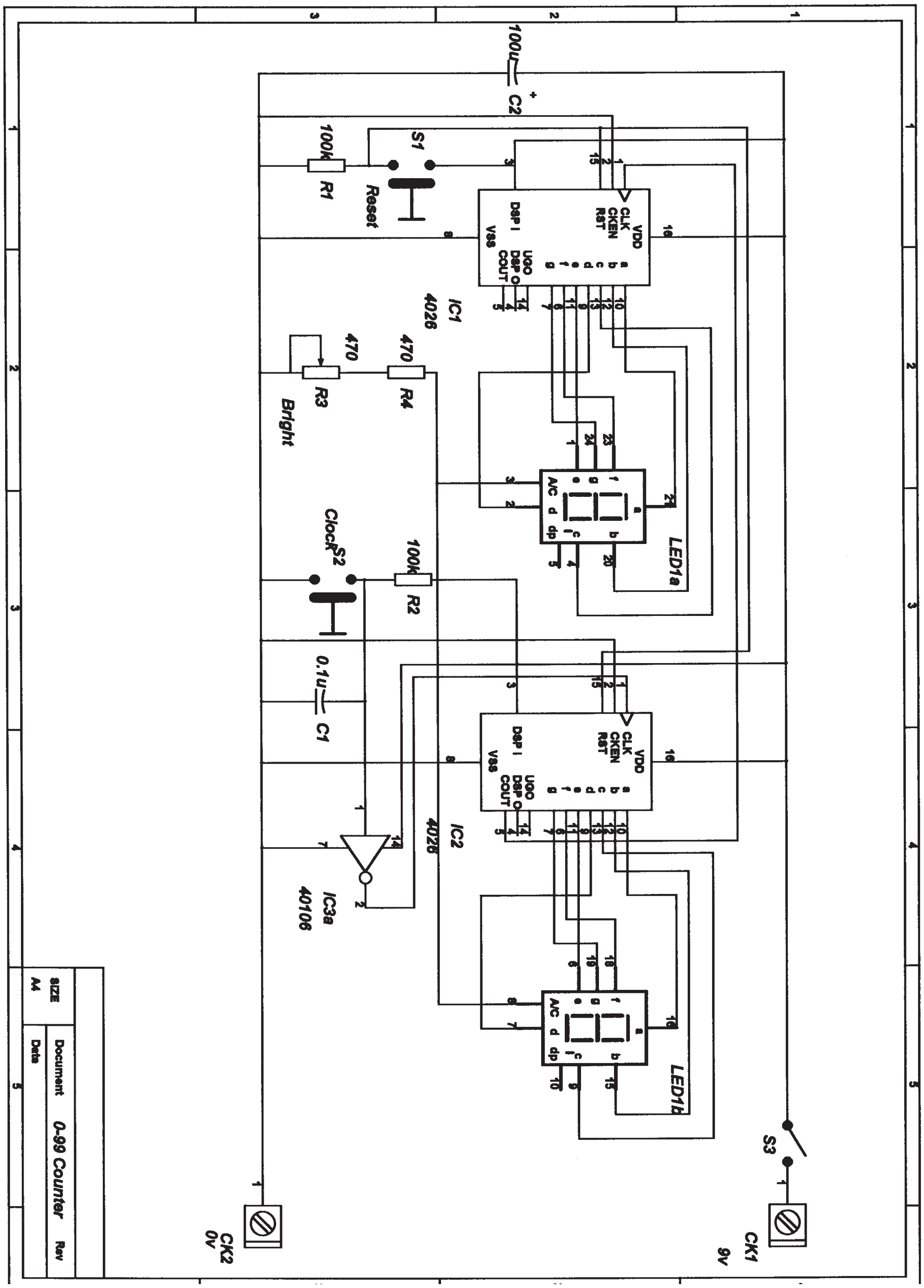
Note1: The two seven segment displays should be mounted on a 24 pin 0.6" pitch DIL socket with socket positions 11, 12, 13 and 14 unused

Note 2: If switch S2 has excessive contact bounce the 0.1µf capacitor could be replaced with a 1µf capacitor

You will need to make a printed circuit board (PCB) onto which to mount the components. To find out about this see Study File 8 (Making a PCB).

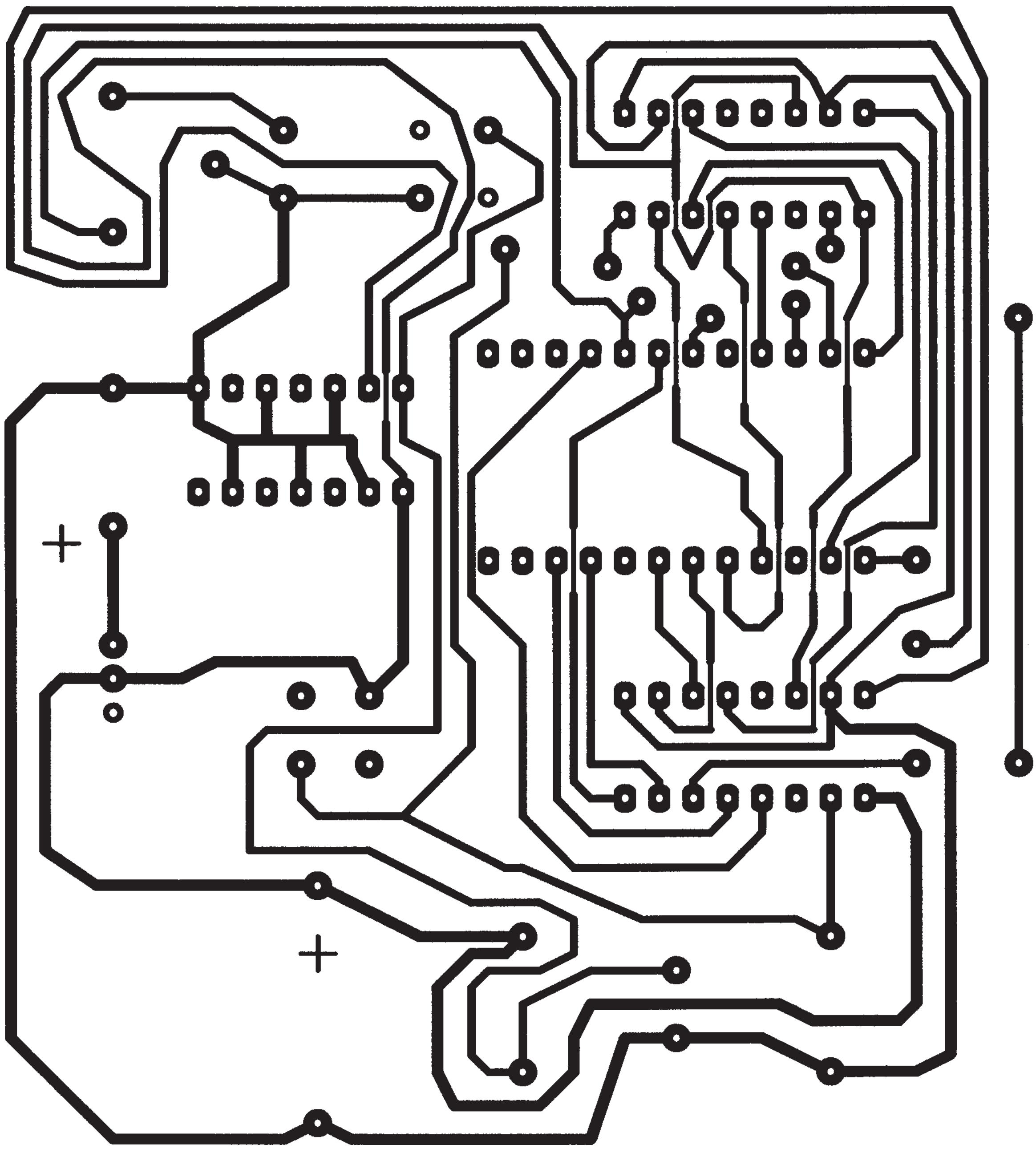
The following four drawings have been produced on a PCB design software package. A disk is also supplied containing a file which includes all four drawings. More information about the PCB design software is given in Study File 8.

SCHEMATIC CIRCUIT DIAGRAM



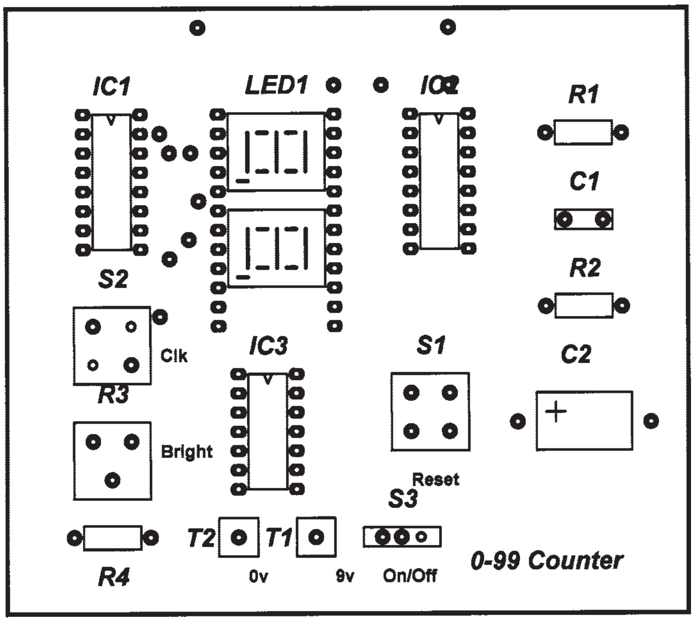
This is the circuit diagram for the complete system redrawn by the design software. The software uses the diagram to create the other three diagrams.

PCB LAYOUT DIAGRAM



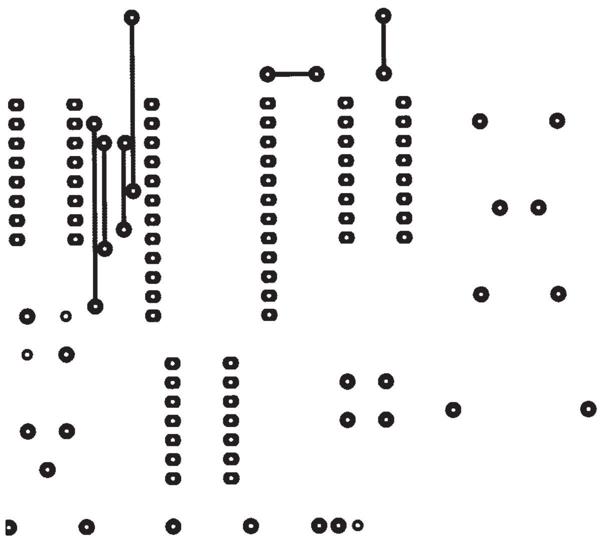
This diagram is used to create the PCB mask on an acetate sheet as described in Study File 8. The diagram is supplied twice normal size so the photocopier should be set to 50% reduction when producing the mask.

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 onto 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. Press the input switch S2 and check to see that the number displayed increases by one. Press several more times to check that both displays are working. Press the reset switch S1 to ensure that both displays reset to zero. Turn the brightness control to see if you can dim the display.

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 COUNTING SYSTEM

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

1. How well does it work?

   Does it count accurately?

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

   Can the system easily be connected and disconnected when it is moved from one piece of equipment to another. If not can you improve the design of the input sub-system?

3. Is the system robust enough to be continually moved from one piece of equipment to another?

   Have you mounted the complete circuit in a project box? Can you improve the layout of the controls?