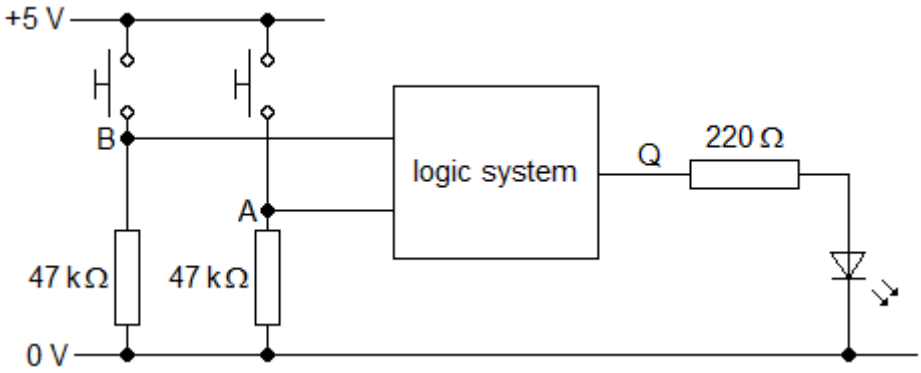
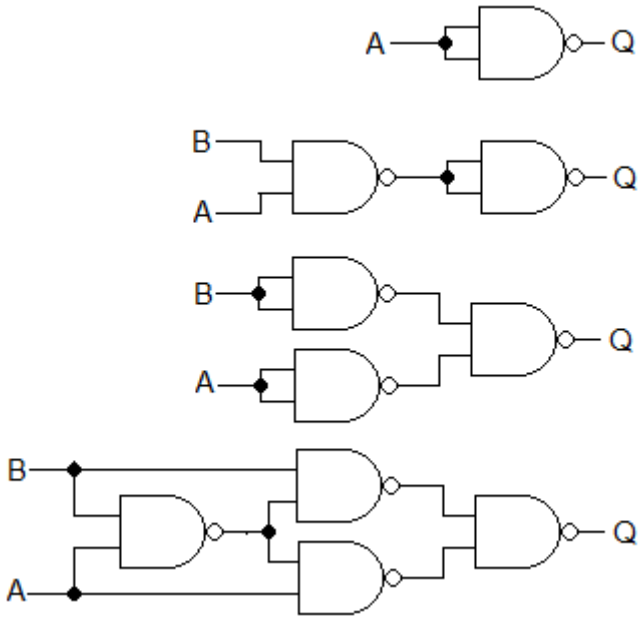
All from NAND gates

You are going to find out how some basic logic gates can be made from just NAND gates.

1 You should already have this circuit assembled on your breadboard.



2 Build each of the logic systems shown below. Use the switches and LED to record a truth table for each system.



3 Each system can be replaced with a single logic gate. Which one?

NOR from NAND

You are going to design, assemble and test a NAND gate circuit which has the truth table of a NOR gate.

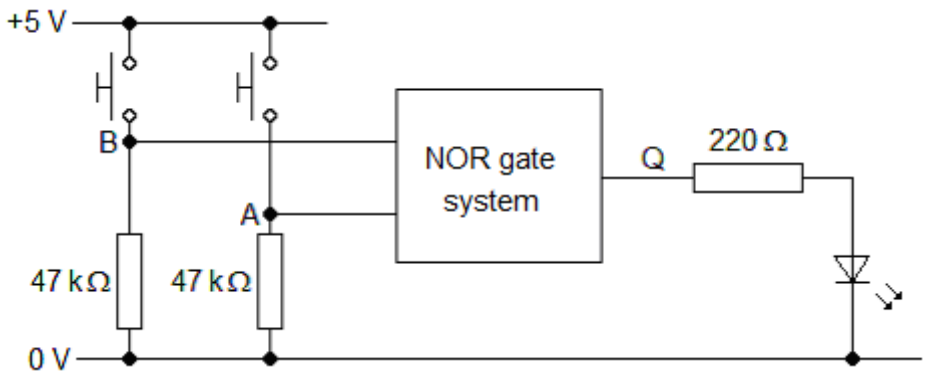
1 Here is the truth table of a NOR gate. Write out a Boolean expression for Q in terms of B and A.

B	A	Q
0	0	1
0	1	0
1	0	0
1	1	0

2 Draw a circuit diagram to show how a NOR gate can be built from NOT and AND gates.

3 Replace each NOT and AND gate with its NAND gate equivalent.

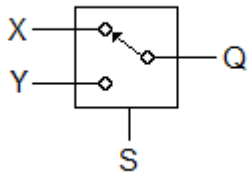
4 Assemble the circuit and test it with switches and LED as shown below.



Multiplexer

You are going to design and test a two-input multiplexer made from just NAND gates.

1 A multiplexer has three inputs, X, Y and Z.
The signal at the output Q is X if S = 1.
When S = 0, Q = Y. Draw up a truth table for the multiplexer.



2 Write down a Boolean expression for Q in terms of X, Y and S.

3 Use the rules of Boolean algebra to show that $Q = S.X + \overline{S}.X$.

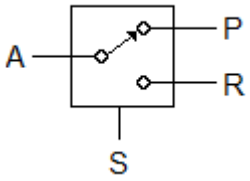
4 Design a circuit using just NAND gates to implement Q. You should only need four gates.

5 Assemble the circuit. Use three switches to provide signals X, Y and S. Use an LED to display the state of Q.

6 Use the switches and LED to verify that the system behaves as required.

7 A demultiplexer is a multiplexer in reverse. Here are its symbol and truth table.

S	A	P	R
0	0	0	0
0	1	0	1
1	0	0	0
1	1	1	0



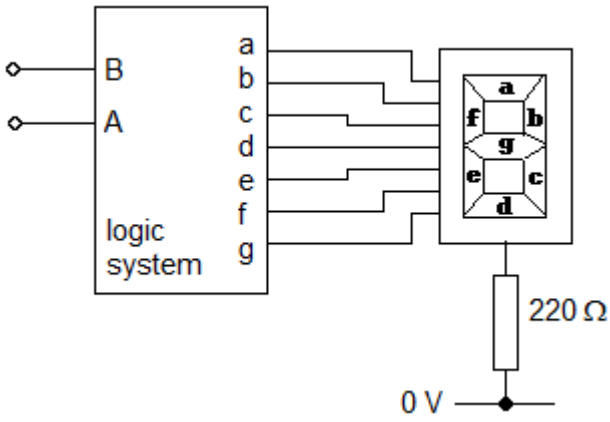
8 Design logic systems to implement P and R using only five NAND gates.

9 Assemble the demultiplexer. You will need a pair of switches and a pair of LEDs to get signal into and out of the system. Verify that it behaves as required.

Binary to seven-segment converter

A seven-segment LED can display all of the numbers from 0 to 9. You are going to design and test a logic system which displays the decimal equivalent of the binary number fed into it.

The logic system has two inputs and seven outputs. The binary number BA determines the number shown on the display by the glowing LEDs, according to this truth table.



BA	display
00	zero
01	one
10	two
11	three

1 Complete this truth table for the logic system.

B	A	a	b	c	d	e	f	g
0	0							
0	1							
1	0							
1	1							

2 Write down seven separate Boolean expressions to show the output of each of the seven sub-systems is related to the two inputs B and A.

3 Draw circuits for each sub-system, using only NAND gates. Remember that:

- any gate output used to source current into an LED should not be used to provide a signal for another gate
- all seven LEDs must be sourced current by logic gates if they are to have the same brightness as each other.

4 Assemble each sub-system in turn and test it with a pair of switches to generate B and A.

5 Now have a go at designing a system which displays the number of switches being pressed (nought, one or two).