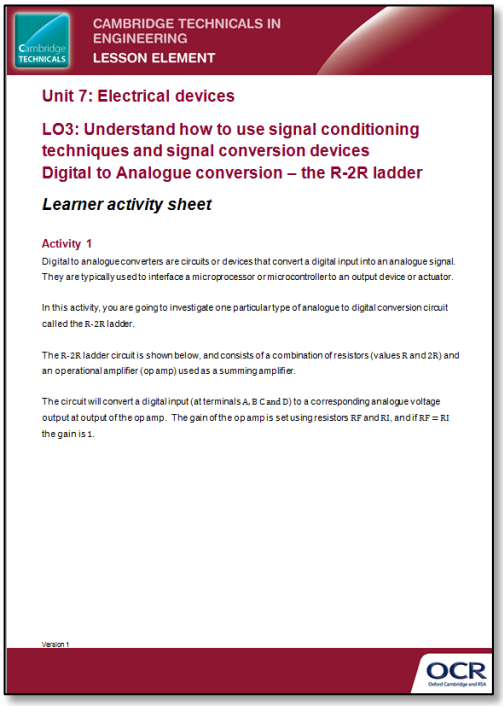
Unit 7: Electrical devices

LO3: Understand how to use signal conditioning techniques and signal conversion devices

Digital to Analogue conversion – the R-2R ladder

Instructions and answers for teachers

These instructions should accompany the OCR resource 'LO3: Understand how to use signal conditioning techniques and signal conversion devices Digital to Analogue conversion – the R-2R ladder' *activity which supports Cambridge Technicals in Engineering Level 3.*


CAMBRIDGE TECHNICALS IN ENGINEERING
LESSON ELEMENT

Unit 7: Electrical devices

LO3: Understand how to use signal conditioning techniques and signal conversion devices
Digital to Analogue conversion – the R-2R ladder

Learner activity sheet

Activity 1

Digital to analogue converters are circuits or devices that convert a digital input into an analogue signal. They are typically used to interface a microprocessor or microcontroller to an output device or actuator.

In this activity, you are going to investigate one particular type of analogue to digital conversion circuit called the R-2R ladder.

The R-2R ladder circuit is shown below, and consists of a combination of resistors (values R and 2R) and an operational amplifier (op amp) used as a summing amplifier.

The circuit will convert a digital input (at terminals A, B C and D) to a corresponding analogue voltage output at output of the op amp. The gain of the op amp is set using resistors RF and RI, and if RF = RI the gain is 1.

Version 1

OCR

The Activity:

In this task the students are tasked with familiarising themselves with a R-2R ladder.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Suggested timings:

2 hours

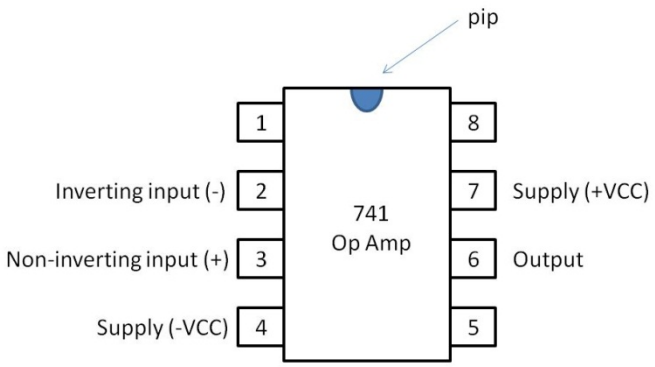
Activity 1

In Activity 1 learners are required to investigate the operation of a digital to analogue converter using an R-2R ladder.

The circuit diagram is shown below.

A good description of operation can be found at the following web link:

http://www.circuitsgallery.com/2012/04/digital-to-analog-converter-using-r-2r.html



741 Op Amp pin out

Output voltage is given by the following formula:

$$Analogue\ Output\ (V) = -\frac{RF}{RI}\left(\frac{D}{2} + \frac{C}{4} + \frac{B}{8} + \frac{A}{16}\right)$$

Learners should concentrate on the basic operation of the circuit, which requires basic knowledge of Ohm's Law, resistors in series and parallel, and the potential divider circuit.

Learners also need to understand the operation of the summing operational amplifier.

Activity 2

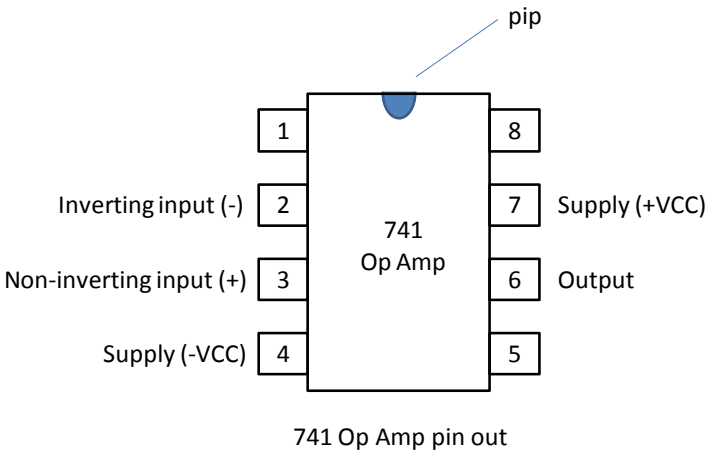
For Activity 2 learners are tasked to perform an experiment to investigate the operation of the R-2R ladder circuit.

Learners could build the circuit using breadboard, veroboard (and soldered construction) or using a printed circuit board.

Alternatively or additionally, the circuit could be simulated using circuit simulation software.

The components required are shown below, including a pin out diagram of the 741 op amp.

Equipment you will need:
Op Amp (741)
Resistors (R = 1K, RF = 1K, RI = 1K) – to make 2R you will need 2 x 1K resistors in series
Breadboard or veroboard
Connecting wire
Power supply (with positive and negative outputs)
Multimeter (or oscilloscope) to measure output voltage



741 Op Amp pin out

Learners should investigate the circuit and tabulate results. Output voltage should be calculated and measured for all combinations of digital inputs. Results should be tabulated and plotted.

A	B	C	D	Output Voltage (calculated)	Output Voltage (measured)
0	0	0	0		
0	0	0	1		
0	0	1	0		
0	0	1	1		
0	1	0	0		

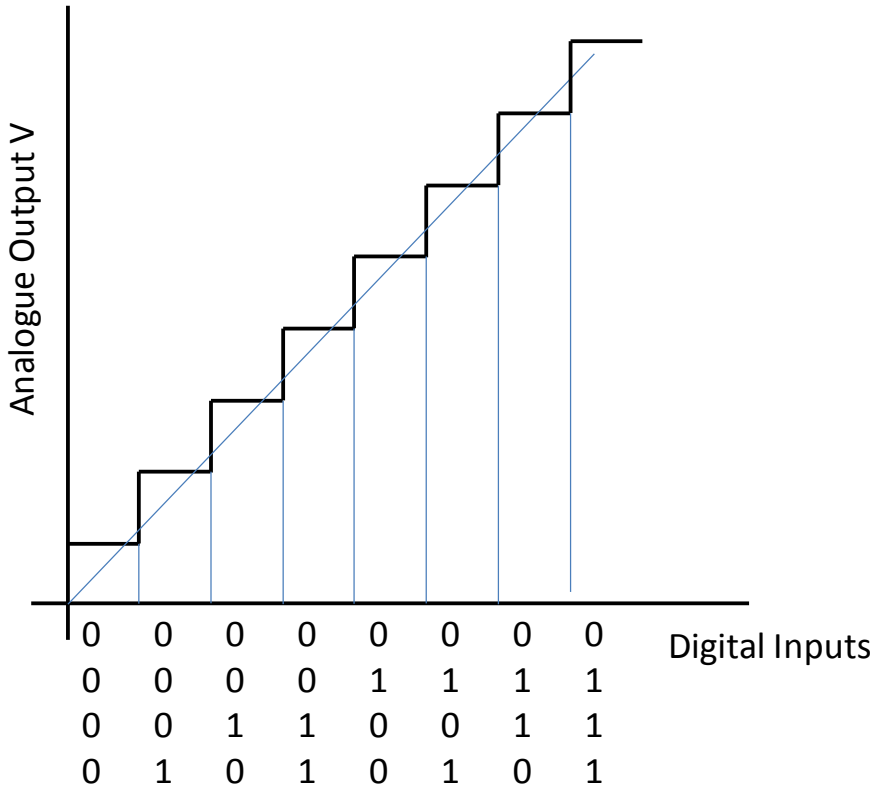
Continue the table to include all combinations of digital inputs to A, B, C and D.

There are 16 combinations in total, and so this is often termed a '16 bit digital to analogue converter'.

Answers to questions:

1. **Does the circuit perform as expected – comment on the shape of the graph?**

Learners should comment on the performance of the circuit. The graph will be a stepped graph of output voltage vs. digital inputs. The graph will be 'linear'. Each step represents changing digital inputs, with small steps for changes in the least significant bit (D) and large steps for changes in the most significant bit (A). Typical graph shape is shown below:



2. **Do the measured values of output voltage agree with the calculated values – and if not, why?**

Learners should comment on the agreement of calculated and measured values. Discrepancies are likely to be due to experimental error (such as misread values) or component tolerances.

3. **How could the circuit be extended to include further digital inputs?**

Further digital inputs can be added by adding more R and 2R components to the ladder to add further bits.

4. **How is the R-2R ladder principle used in the design of commercial Digital to Analogue converter integrated circuits?**

The R-2R ladder is used to form the internal workings of many commercial digital to analogue converter integrated circuits. These typically have 8, 10, 12 or 16 digital inputs, and an analogue output. Learners could explore suitable manufacturer data sheets.

Teachers could produce a similar activity for learners to explore the operation of analogue to digital conversion.

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