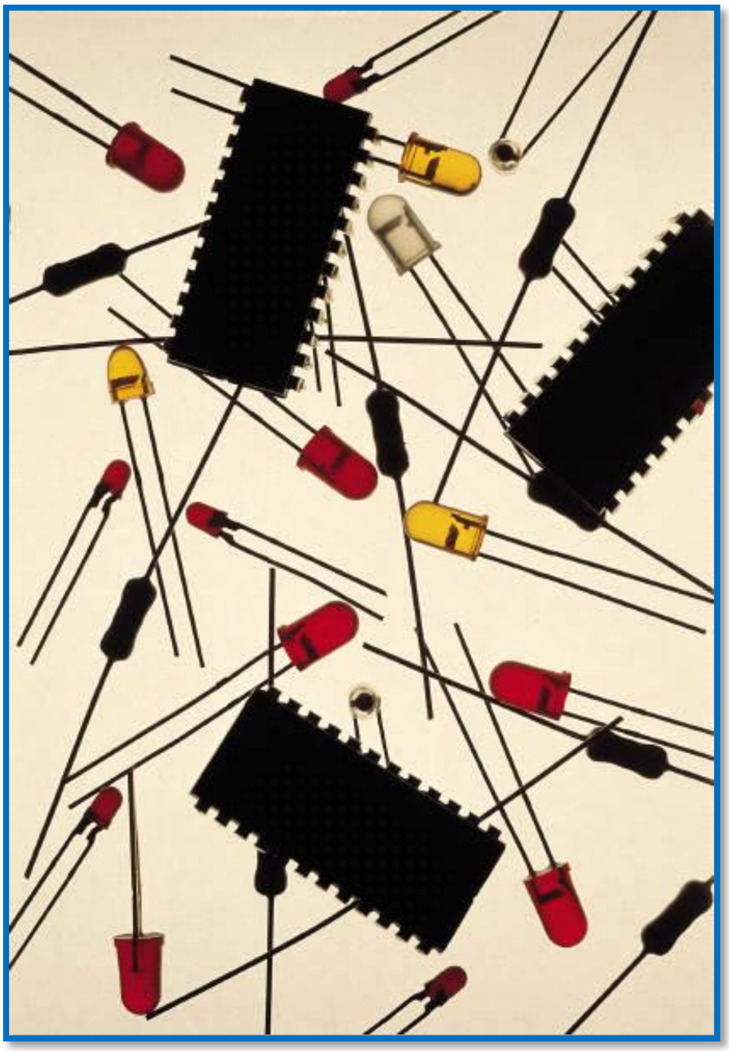
ANALOGUE AND DIGITAL ELECTRONICS

TEACHING NOTES



Joaquim Crisol
Llicència D, Generalitat de Catalunya
NILE Norwich, April of 2011

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0 GENERAL INDICATIONS.

These teaching materials are organized in different files as follows:

- Context.pdf: Here you can find out about the context in which these materials have been created.
- Lesson_plans.pdf: There is a lesson plan for each unit with the learning outcomes, the assessment criteria and the 4Cs.

- Student.pdf: This is the student's workbook. Every student should have a paper copy to work on. It includes theory and activities.

- Supplementary materials:

  - unit1.pps, unit2.pps, unit3.pps, revision.pps: These are the presentations the teacher can use. They are designed to be used on an IWB. They contain everything that is on the student's workbook plus the answer keys. It is possible to teach the lessons without these files, just with the teaching notes. However, using this slides will surely save time and allow quick revision. Teachers can decide to do some activities themselves using the blank activities, make students do them or directly show and give the answers on next slide. I also suggest using them to review content from previous lessons at the beginning of lessons.

  - u_a_.mp3: audio files for the texts that have to be dictated or just listened to. You can play them from the power point in two ways. When an activity requires an audio file you will see the name of the file and a speaker on that slide. If you click on the speaker you will hear the audio without any player window. Alternative, if you click on the audio file name an external audio player will open to play the file. This files should be in the same folder as the presentations are.

  - Worksheets: These are to be handed out to students on an as needed basis.
    - A/B: These are handed in only for certain activities where students work in pairs. They are taken back afterwards.
    - Summative evaluation: a sample test for the end of the three units.

  - logisim-generic-2.7.1.jar: An open-source graphical tool for designing and simulating logic circuits. You can also download it from

    http://ozark.hendrix.edu/~burch/logisim/index.html.

- Teaching_notes.pdf (this document):

  - **Planning table**: Teachers can use it to assign time to tasks, to keep track of the work done, to write notes, etc.

  - Table for **formative assessment**: It has been designed for teachers to record when a student achieves a learning outcome from the three units. There are 2 items for unit 1, 3 items for unit 2 and 3 more items for unit 3. The teacher should choose some activities to check those items. The last 4 items are more general (use of English, autonomy and group work).

- List of materials needed for building the analogue electronic circuits.
- Instructions for downloading and using the free logic simulation software.
- Teaching notes for the three units including an index for the slides and the procedure and keys for every activity.

Preteaching and eliciting vocabulary: For every unit, lesson or activity the teacher may consider to **preteach** some anticipated new words for the students or **elicit** them. Some other words may be left for **acquisition**. As this depends on the previous knowledge of the subject and L2 of the class, I leave this as a decision to be taken by the teacher for every particular class.

From unit 2 activities can be quite difficult for some students. Probably it will be necessary to do more **repetition work** for the whole class or just for some students, before moving on or as **homework**. I also leave those decisions for the teacher, as needs for each group are different. So, depending on the abilities of the group, the timing for units 2 and 3 can be expanded considerably.

Before you start teaching unit 1 explain to the students about the "**useful language activity**" at the end of the workbook. They have to record by themselves any new important vocabulary and useful sentences as they find them during the lessons.

1. Introduction to electronics.	**3 h**		**Notes**
1.1. Electricity and electronics.	0.5 h		
A1. Name it.			
A2. Definitions.			
A3. Electric, electronic?			
1.2. Past, present and future...	1 h		
A4. Triple match.			
A5. Timeline.			
A6. Applications of chips...			
A7. E-waste.			
1.3. From analogue to digital ...	0.5 h		
A8. Block diagrams.			
A9. A/D/Binary signals.			
A10. A/D/Binary objects.			
A11. Advantages and noise.			
A12. A/D converters.			
A13. True/false.			
Self assessment 1.			
2. Analogue electronics.	**6 h**		
2.1. Resistors.	3 h		
A1. Ohm's law			
A2. Ω and multiples.			
A3. Colour code.			
A4. Types of resistors.			
A5. Voltage dividers.			
2.2. Capacitors.	1 h		
A6. Function and units.			
A7. Charge and discharge.			
2.3. Diodes.	1 h		
A8. Description, polarisation.			
A9. Basic calculations.			
A10. LED calculation			
A11. Circuit design.			
2.4. Transistors.	1 h		
A12. Basic function.			
A13. Amplifier function.			
A14. Switch function.			
Self assessment 2.			
2.5. Building real circuits.	**3h (opt)**		
C1: Rectifier bridge.			
C2: Light regulator.			
C3: Timer.			

3. Digital electronics.	**4 h**		
3.1. Numeral systems. Binary.	1 h		
A1. Binary system.			
A2. Binary-decimal.			
A3. Binary addition.			
3.2. Boolean logic. Logic gates.	1.5 h		
A4. Logic operators and gates.			
A5. Gate technologies.			
A5. Gate technologies.			
3.3. Logic circuit design.	1.5 h		
A6. Circuit analysis.			
A7. Circuit description.			
A8. XOR circuit.			
A9. Circuit design.			
3.4. Simulation work. (opt)	3 h		
S1: Logisim basics.			
S2: Logic circuits.			
S3: Adding and visualising.			
4. Revision, assessment.	**2 h**		
Visual summary.			
Teaching activity.			
Useful language.			
Summative test.			

Can the student...																														
recall main developments in electronics?																														
compare analogue and digital systems?																														
identify electronic components?																														
do calculations for basic circuits?																														
build circuits from a diagram?																														
convert numbers to/from binary?																														
transform logic expressions into circuits?																														
use simulation software.																														
manage English in class?																														
concentrate and work independently?																														
cooperate with others?																														
evaluate work?																														

Analogue electronics kit

Electronic kit components. PENDING.

Logic simulation software

Logisim is an open-source (GPL) powerful logic simulator. It runs on any machine supporting Java 5 or later; special versions are released for MacOS X and Windows. The cross-platform nature is important for students who have a variety of operating systems.

- Official website: http://ozark.hendrix.edu/~burch/logisim/
- Download webpage: http://sourceforge.net/projects/circuit/
- Logisim on Wikipedia: http://en.wikipedia.org/wiki/Logisim

How to execute the java file in Windows:

- Double clicking on the file should be enough.
- If it doesn’t work you have to execute it with javaw.exe. You can right click on it and search for javaw.exe.
- I recommend that you to associate .jar files to this program. If you find it difficult you can use “javafix” tool to do it: http://johann.loefflmann.net/en/software/jarfix/index.html

How to execute the java file in Linux:

- Open a terminal window where you have logisim-generic-2.7.1.jar.
- Then execute this command line: java -jar logisim-generic-2.7.1.jar

You can download newer versions and tutorials from the official website.

1 INTRODUCTION TO ELECTRONICS.

3 h	Classroom	unit1.pps , w/s 1A, 1B, u1.mp3

Slides for unit 1:

1. Mindmap of the 3 units.
2. Activity 1: name the objects.
3. Activity 1: answers.
4. Activity 2: definitions of electronic and electrical technology.
5. Activity 2: answers.
6. Activity 3: classify as electric or electronic.
7. Activity 3: answers.
8. Activity 4: match name-picture-definition for vacuum tubes, transistor and IC.
9. Activity 4: answers.
10. Summary of history of electronics 1.
11. Summary of history of electronics 2.
12. Activity 5: find out the year and complete the timeline.
13. Activity 5: answers.
14. Activity 6: fill in the table year-invention-application.
15. Activity 6: answers.
16. Activity 7: images of e-waste.
17. Activity 7: questions on e-waste.
18. Activity 7: answers e-waste.
19. Block diagrams explanation.
20. Activity 8: block identification.
21. Activity 8: block identification.
22. Activity 8: answers.
23. Activity 8: answers.
24. Analogue, binary, digital explanation.
25. Activity 9: label the signals.
26. Activity 9: answers.
27. Activity 10: identify as analogue, digital or binary.
28. Activity 10: answers.
29. Activity 11: text comparing analogue and digital and the effect of noise.
30. Activity 11: answers.
31. Activity 11: graphs with noise.
32. Activity 11: answers.
33. Activity 12: text on analogue-digital conversion.
34. Activity 12: answers.
35. Activity 12: choose the right answer.
36. Activity 12: answer.
37. Activity 13: True or false.
38. Activity 13: answers.
39. Self assessment.

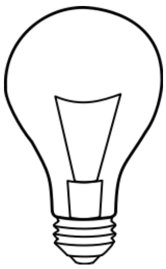
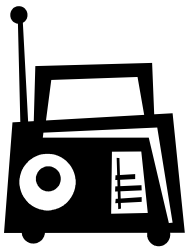
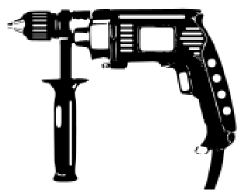
1.1 Electricity and electronics.		
30 min	Classroom	unit1.pps

Before you start with Activity 1 you can show and comment on slide 1 with a mindmap of the contents of the 3 units.

Activity 1	Individual, warm-up	unit1.pps (2,3)

- Show slide 2 for activity 1. Students should know these words from previous courses.
- Give them time to write the answers in pencil in their workbooks.
- Ask some students for the answers. With an IWB some of them can write them on the ppt.
- Finally show the answers on slide 5. Let them check their answers.

K1 Do you know the names of these objects?

			
Light bulb	*Mp3-player*	*Hair dryer*	*Television*
			
Radio	*Computer*	*(Electric) fan*	*Drill*

Activity 2	Individual	unit1.pps(4,5)

- Show slide 3 with the definitions of electrical and electronic technology.
- Let the students guess and fill in the blanks.
- Ask some students for the answers. With an IWB some of them can write them on the pps.
- Finally click on the pps to show the right answers

K2 Complete the definitions of electronic and electrical technology.

Electrical	*technology*	*energy*	*Electronics*

Electronics is the branch of science and ***technology*** that deals with electrical circuits applied to information and signal processing.

Electrical technology deals with the generation, distribution, switching, storage and conversion of electrical ***energy***.

Activity 3	Individual, pairs	unit1.pps(6,7)

- Show slide 6 with the empty table to classify objects from exercise 1 according to definitions given in exercise 2.
- Let students check their answers orally with their partners using the scaffolding.
- Finally ask any of them for the answers and check with slide 7.

K3 Classify the objects from the first activity as electrical or electronic.

Electrical	*Light bulb* *Hair dryer* *(Electric) fan* *Drill*
Electronic	*Mp3-player* *Radio* *Computer* *Television*

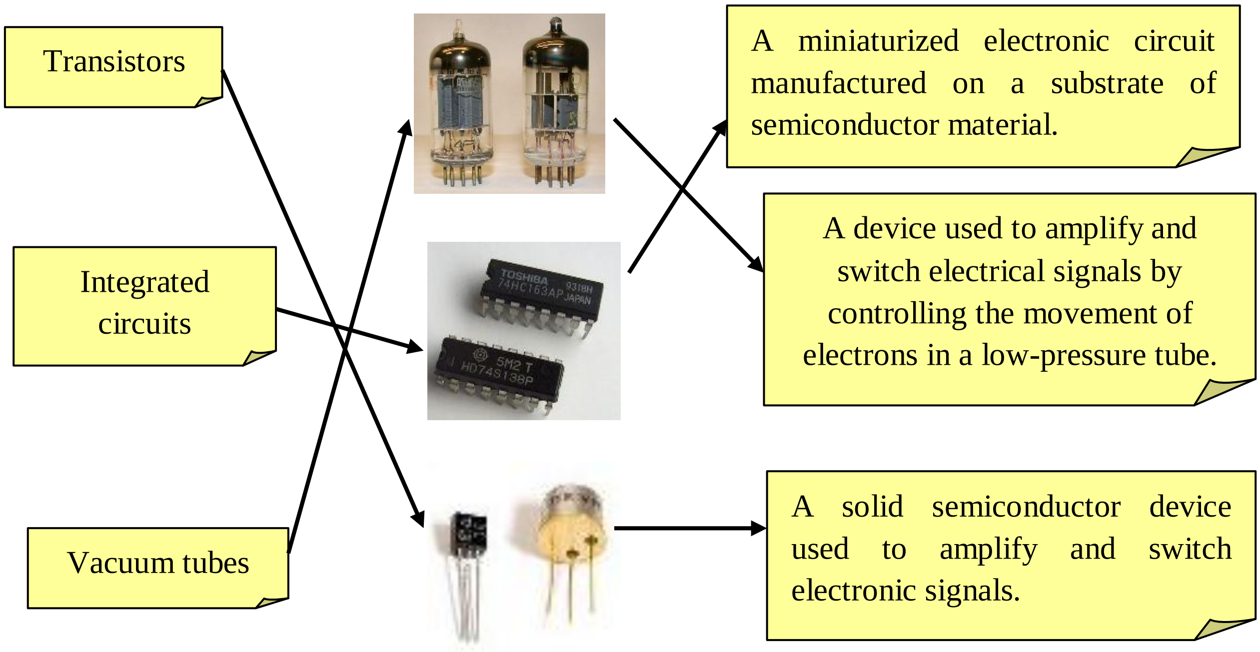
1.2 Past, present and future of electronics.

60 min	Classroom	unit1.pps, u1a7.mp3, video from youtube

Activity 4	Individual	unit1.pps(8,9)

- Show slide 8 to triple match name, picture and definition. Tell students those three developments have been very important in the evolution of electronics.
- You can ask some of them for their answers and why they have guessed that.
- Show the right answers in slide 9. Reassure them that they are going to read more about those objects in next activity.

K4 Match these pictures with their names and definitions.



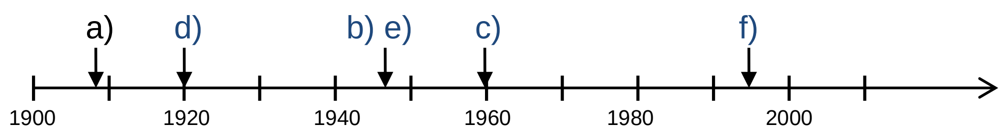
Activity 5	Individual	unit1.pps(10,11,12,13)

- Tell students to read the text by themselves in their workbooks.
- It may be necessary to explain some words they don't understand. For that you have the text on slides 10 and 11.
- Then tell them they should search, highlight and transfer the information they are asked for in the activity and draw the time line.
- Finally, you or a student can do the activity on the IWB (slide12) or directly show the answers on slide 13.

K5 Find out what year these things happened by reading the text below.

a) 1904 Invention of the vacuum tube.	d) 1920 Start of radio broadcasting.
b) 1947 Invention of the transistor.	e) 1947 Start of black and white television..
c) 1960 First microchip.	f) _ _ _ _ First mobile phone in your family.

Place them on the timeline.



Activity 6	Individual, check in pairs	unit1.pps(14,15)

- Students should read the text in depth individually to fill in the table.
- Let them write answer sentences as in the model. They should practice these sentences when checking answers with their partner. There is not a closed answer for the applications.
- Ask some students for the answers orally. You can show the proposed answers on slide 15.

K6 Fill in the gaps with data from the text above.

Date	Invention	Applications
1904	*Vacuum tubes*	*To amplify electric signals*
1947	*Transistor*	*To amplify electric signals*
1960	*Integrated circuit*	*Microcomputers, mobile phones*

Activity 7	Individual, whole group	unit1.pps(16,17,18), u1a7.mp3, youtube

- This is quite an open and creative activity for the students. The purpose is to create awareness and discussion more than getting the right answer.
- Let them see the two following pictures (16) and read the questions.
- Then you should play the audio file or read the text below one or two times.
- At this point they should answer questions a), b) and c).
- Now, show the video from Greenpeace (link on slide 16) before asking them to write proposals for question d). It can also be done without the video.
- Use slides 17 and 18 to answer the questions. For question d) you can have a debate. Let students explain proposals to the whole group and finally try to reach an agreement to choose the best ones.

Text to read or play:

The world is consuming more and more electronic products every year. This has caused a dangerous explosion in electronic scrap (e-waste) containing toxic chemicals and heavy metals that cannot be disposed of or recycled safely. But this problem can be avoided. Every year, hundreds of thousands of old computers and mobile phones are dumped in landfills or burned. Thousands more are exported, often illegally, from Europe, the US, Japan and other industrialized countries, to Asia and Africa. There, workers at scrap yards, some of whom are children, are exposed to a cocktail of toxic chemicals and poisons.

Optional video: http://video.google.com/videoplay?docid=5944615355863607664#

K7 Look at these pictures and listen to the text. Then answer the questions below.

a) What is e-waste? *E-waste is old electronic rubbish.*
b) Where does most e-waste go? *Most e-waste is exported to poor countries in Asia and Africa.*
c) Do you think e-waste is toxic? *I think it is toxic because electronic products contain heavy metals such as lead and mercury and hazardous chemicals.*

d) E-waste will be a bigger problem in the future because more and more people use more and more electronic devices and change them more often. Talk to your partner and try to find a solution to the e-waste problem.
   - *Governments should ... (open answer)*
   - *We all should ...(open answer)*
   - *Electronic products should ... (open answer)*

1.3 From analogue to digital electronic systems.

90 min	Classroom	unit1.pps , worksheets 1A 1B

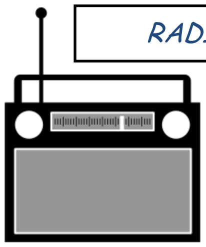
Activity 8	Individual, pairs, class.	unit1.ppt (19,20,21,22,23)

- Show slide 19 and explain how we can represent electronic systems with block diagrams.
- Tell students to label the objects, identify the blocks and explain them using the word and sentence bank below. (slides 20, 21)
- After that they have to practice explaining the diagrams with their partners following the model. Assess some of them individually.
- Check the answers (slide 22, 23) and make a few of them explain the diagrams.
- Correct grammar and pronunciation. Other students can give their own feedback.

K8 Label the objects by using the language bank below and identify the input and output block for each one.

MEGAPHONE

Input	Process	Output
MICROPHONE	ELECTRONICS	LOUDSPEAKER
It converts sound to electrical signals	It processes electrical signals	It converts electrical signals to sound.



RADIO

Input	Process	Output
AERIAL	ELECTRONICS	LOUDSPEAKER
It takes in electromagnetic waves and produces an electrical signal.	It processes electrical signals.	Transforms electrical signals to sound.

DIGITAL THERMOMETER

Input	Process	Output
TEMPERATURE SENSOR	ELECTRONICS	TEMPERATURE DISPLAY
It senses changes in temperature and produces an electrical signal.	It processes electrical signals.	It gives a readout of temperature.

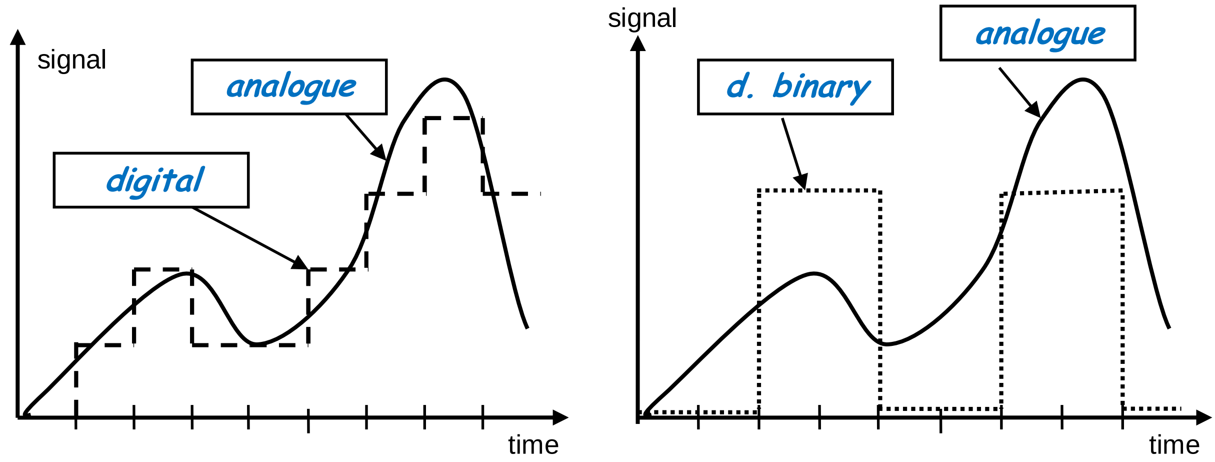
CALCULATOR

Input	Process	Output
KEYPAD	ELECTRONICS	DISPLAY SCREEN
Push-buttons that generate electrical signals.	It processes electrical signals	It converts electrical signals to visible numbers

Activity 9	Individual	unit1.pps(24,25,26)

- Read aloud and explain slide 24 about analogue, digital and binary signals. Explain vocabulary if needed.
- Next, students should transfer the information and label the four signals on slide 24 and justify their decision matching the three sentences below.
- Read the solutions on slide 26 and clarify any doubts before moving on.

K9 Label these signals as analogue, digital or digital binary.

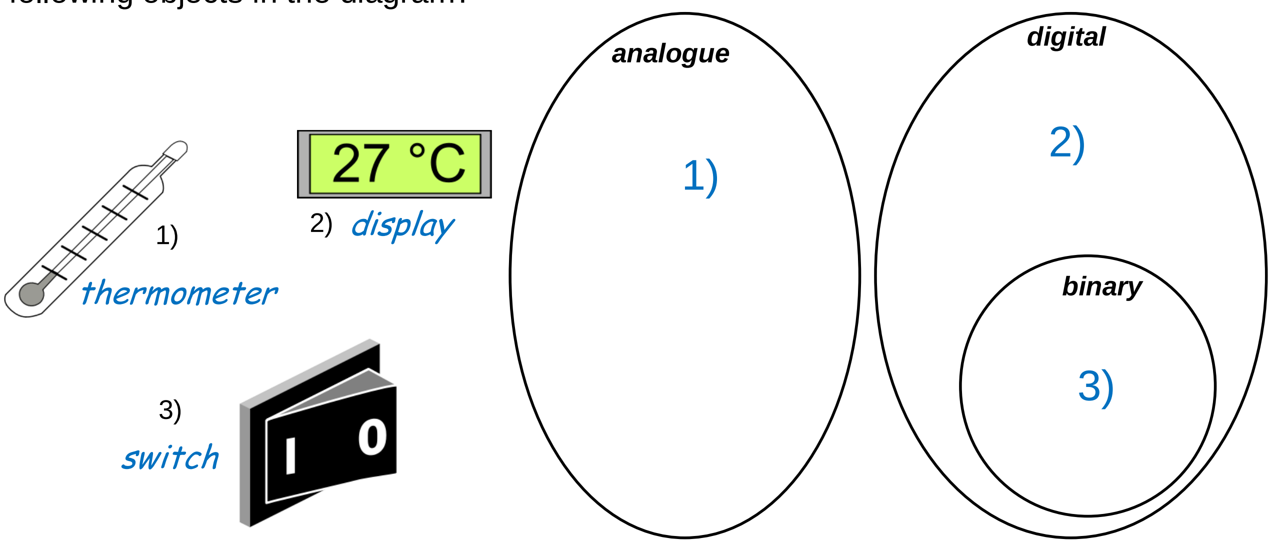


The dashed signal is	digital binary	because it has any value.
The continuous signal is	analogue	because it has only two values
The dotted signal is	digital	because it has only certain values.

Activity 10	Individual, pairs, group	unit1.pps(27,28)

- Show slide 27 and ask students to label the three objects and classify them in the Venn diagram according to the last slide.
- Then make them check answers orally with their partner using the model.
- Ask three of them for the answers. Check with slide 28.
- Now, give them some time to add a new example of each in the Venn's diagram. Check some of them with the whole group.

K10 We can think of objects as analogue or digital. Can you write the names of the following objects in the diagram?



Activity 11	Individual, pairs, group	unit1.pps(29,30,31,32), worksheets 1A, 1B

- Show slide 29 with the gapped text for the activity. Ask students to read it on the screen or on their workbooks.
- Make them work in pairs with an A member and a B member. Hand out worksheets A and B.
- Individually, they have to copy text A or B into their workbooks.
- After that they have to dictate the text they have copied to each other.
- Next, they have to read the whole text and agree on a heading. At this point they may ask for some vocabulary.
- Show slide 30 with the whole text. Listen to some proposals or the heading and agree on one.
- Move on to slide 31. Ask them to draw what they think is the original signal without noise individually and complete the sentence below the signals.
- Ask some of them to draw them on the IWB. Demonstrate that there are many possibilities for the analogue signal and what that means.

K11 Mutual dictation:

HEADING: *Advantages of digital signals and noise.*

Signals in nature are analogue. For example, sound is an air pressure wave(a). It is analogue because it can be any value.

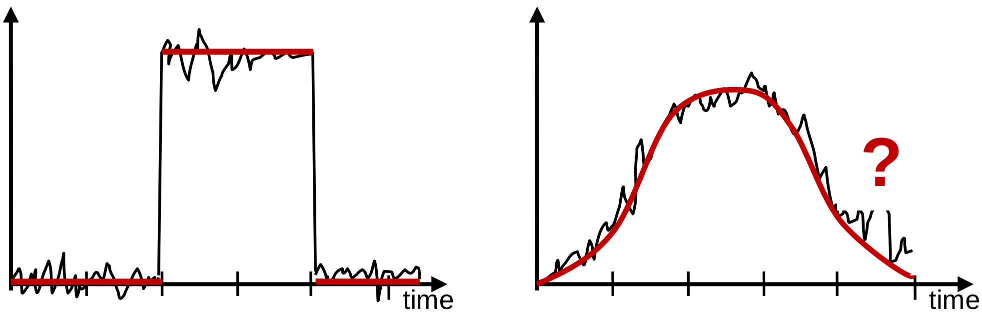
Digital signals have many advantages(b):

- *They can be converted to numbers and easily processed by computers(a).*
- *They are easy to store and to compress using mathematical algorithms.*
- *Noise does not affect them (b) as much as to analogue signals.*

*When data is transmitted, processed or stored a certain amount of **NOISE** enters into the signal (a).*

With an analogue signal, noise cannot be distinguished from the original signal (b). We have distortion. In a digital signal, noise will not matter, as any signal close enough to a particular value will be interpreted as that value.

Draw the original signal in colour. Which one is more difficult to rebuild?



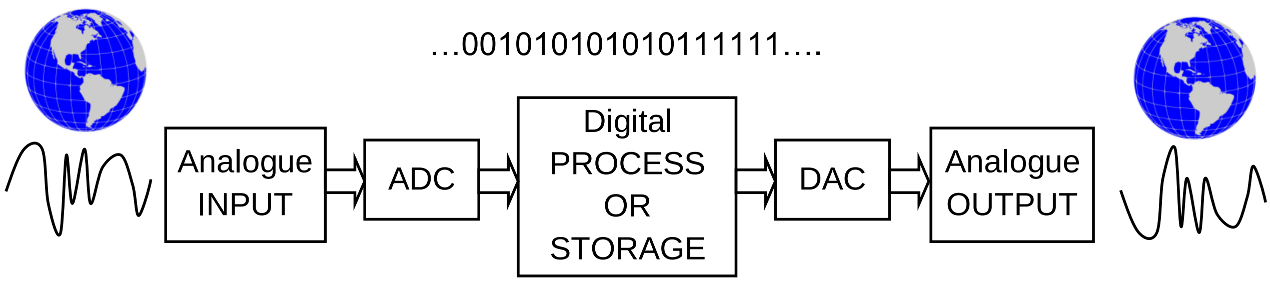
The digital binary signal is easier to reproduce because it can have only two values.

Activity 12	Individual	unit1.pps(32,34,35,36), u1a12.mp3
• Show gapped text on slide 32. Play the audio file or read aloud the complete text. Students have to fill in the gaps. • Explain and respond to questions about the text. • Show slide 35 with the 4-option question and ask them to choose one and give reasons for it. • Get answers from some students. Contrast them with the input text. Finally show the right answer and the explanatory diagram on slide 36.		

K12 Listen to the text about the analogue-digital conversion process. Fill in the gaps and answer the final question.

Analogue signals are processed by analogue circuits and digital signals are processed by digital circuits. In between, we can use these electronic circuits to convert from analogue to digital and vice versa.

- *ADC: analogue-to-digital converters*
- *DAC: digital-to-analogue converters*

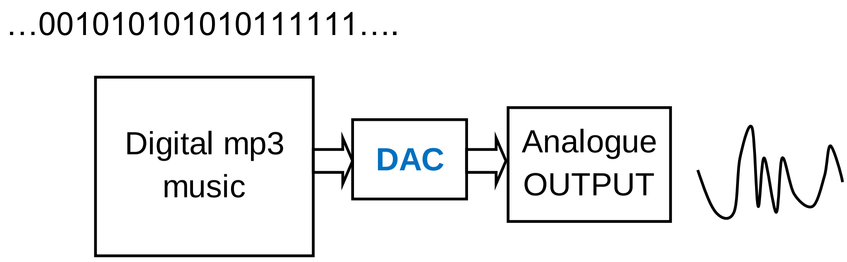


For example, we can get sound with a microphone and analogue electronics. Then an ADC converts this signal to digital data. This data can be processed and stored in a digital format, such as mp3.

Home electronics used to be analogue but nowadays everything is mainly digital. So, we have digital TV, digital photography, digital audio, etc.

Circle the right answer:

a) DAC stands for analogue-digital-conversion.
b) Modern electronics is mostly digital.
c) **To play mp3 music we have to use a DAC.**
d) Sound is a digital signal.



Activity 13	Individual	unit1.pps(37,38)

- This activity is intended to check understanding of texts in activities 11 and 12.
- Students have to read all the statements, decide if they are true or false. In the second case, they have to produce the right statement. Use slide 37.
- Go through each sentence and reason the answer with the participation of some students.
- Show the corrected activity on slide 38.

K13 Decide if these sentences are true or false. If they are false change them so that they are true.

T / F A cassette tape is the digital evolution of a CD (compact disc).

A CD is the digital evolution of a cassette tape.

T / F DVB (digital video broadcasting) has no noise because it is an analogue signal.

DVB has no noise because it is a digital signal.

T / F Analogue photography can be easily modified, compressed and transmitted.

Digital photography can be easily modified, compressed and transmitted.

T / F An ADC converts digital signals to analogue.

An ADC converts analogue signals to digital.

T / F Digital electronic systems are older than analogue systems.

Digital electronic systems are newer than analogue systems.

T / F All digital signals are binary signals.

All binary signals are digital signals.

SELF ASSSESSMENT	Individual	unit1.pps(39)

- Show the self assessment table and ask students to fill it in.
- If they answer NO to some question they should revise the exercises at home.
- Assign a few minutes at the beginning of next lesson to answer possible questions.

QUESTION	No	More or less	Yes
Can I order the main developments in electronics and say what decade they happened?			
Do I know what problems e-waste can cause and how to avoid them?			
Can I draw a block diagram for a basic electronic system?			
Can I give examples of analogue, digital and binary signals?			
Can I compare analogue and digital systems?			

2 ANALOGUE ELECTRONICS.

6 h	Classroom, workshop	unit2.pps, electronic kit

Slides for unit 2:

1. Title.
2. 1a: magnitudes.
3. 1a: answers.
4. 1b: Ohm's law, formulations.
5. 1b: answers.
6. 1c: Ohm's law, proportionality.
7. 1c: answers.
8. 1d: Ohm's law, graphs.
9. 1d: answers.
10. 2a: Ω multiples.
11. 2a: answers.
12. 2b: calculations (1).
13. 2b: answers.
14. 2b: calculations (2).
15. 2b: answers.
16. 3a: colour code, blanks.
17. 3a: answers.
18. 3b: resistor values.
19. 3b: answers.
20. Tolerance.
21. 3c: max/min resistance.
22. 3c: answers.
23. 3d: propose resistors.
24. 3e: describe resistor.
25. 4a: variable resistors.
26. 4a: answers.
27. Special resistors table.
28. 4b: explain special resistors.
29. 4b: answers.
30. 4c: visual classification.
31. 4c: answers.
32. Voltage dividers.
33. 5a: voltage divider calculation.
34. 5a: answers.
35. 5b: predicting voltage divider.
36. 5b: answers.
37. 5c: potentiometer in a voltage div.
38. 5c: answers.
39. 6a: capacitors blank fill.
40. 6a: answers.
41. 6b: Farad and submultiples.
42. 6b: answers.
43. Text on types of capacitors.
44. 6c: questions on types of capacitors.
45. 6c: answers.
46. RC for timing purposes.
47. 7a: sequence charge and discharge.
48. 7a: answers.
49. Time constant graph.
50. 7b: time constant calculations.
51. 7b: answers.
52. 7c: describe charge and discharge.
53. 7c: answers.
54. Introduction to diodes.
55. 8a, 8b: basic questions.
56. 8a, 8b: answers.
57. 8c: draw wires on a circuit picture.
58. 8c: answers.
59. How to calculate forward current.
60. 9: calculate the current (1).
61. 9: answers (1).
62. LED theory.
63. 10: current calculation.
64. 10: answers.
65. 11a: reason double polarisation.
66. 11a: answers.
67. 11b: rectifier bridge design.
68. 11b: answers.
69. 12a: transistor (blanks 1).
70. 12a: transistor (blanks 2).
71. 12a: answers 1.
72. 12a: answers 2.
73. 12b: gain calculations.
74. 12b: answers.
75. 12c: base current calculation.
76. 12c: answer.
77. 13a: how to control Ic.
78. 13a: answers.
79. 13b: current amplifier.
80. 13b: answers.
81. Transistor as a digital switch.
82. 14a: Identify circuit.
83. 14a: answers.
84. 14b: describe timer.
85. 14b: answer.
86. Self assessment.
87. Circuit 1: bridge rectifier.
88. Circuit 1 with values.
89. Circuit 2: light regulator.
90. Circuit 2 with values.
91. Circuit 3: timer.
92. Circuit 3 with values.

2.1 Resistors.		
3 h	Classroom	unit2.pps, some real resistors.

Activity 1a	Individual	unit2.pps (2,3)

- Students should know the symbol of a resistor, the four electric magnitudes and their units from previous school years. The purpose of this activity is to remind them of that and to introduce English vocabulary as a warm-up.
- Ask them to fill in the table on slide 2. You can to draw a basic circuit to remind them.
- Show answers on slide 3. Check spelling and pronunciation with them.

K1a Remember the main electrical magnitudes and find the unit for each one.

Magnitude	*Unit*
Voltage (V)	*Volts (V)*
Electric current (I)	*Ampere (A)*
Power (P)	*Watt (W)*
Electric resistance (Ω)	*Ohms (Ω)*

Activity 1b	Individual	unit2.pps (4,5)

- Students already learnt Ohm's law in previous years. Now they should understand it better. For that, they need the vocabulary to express formulas.
- Show slide 4 and read the formulae: "V equals I by R", "I equals V over R". Give them time to match the four descriptions to one of the formulae.
- Ask some of them to read their answers before showing the key on slide 5.

OHM'S LAW connects resistance, voltage and current in an electrical circuit. There are many ways to express this relationship: with text, with formula and graphically.

a) Formula for finding the voltage across a resistor for a given current. $V = I \cdot R$

b) Formula for finding the current through a resistor for a given voltage. $I = \frac{V}{R}$

K1b Which formula represents these formulations of Ohm's law better, a) or b)?

[**a**] The voltage (V) across a resistor is proportional to the current (I) passing through it, where the constant of proportionality is the resistance (R).

[**b**] When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage.

[**a**] Voltage across a resistor equals the current through it multiplied by the resistance.

[**b**] Current through a resistor equals the voltage across it divided by the resistance.

Activity 1c	Individual	unit2.pps (6,7)

- In this short activity students learn the language to express magnitude dependence.
- Show slide 6 with the activity. Make it clear that more than one can be right.
- Check answers with slide 7.
- You can ask them for some more examples using the same grammatical structure.

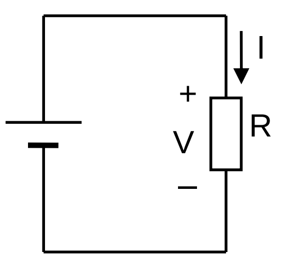
K1c Choose the right answer or answers (a and c).

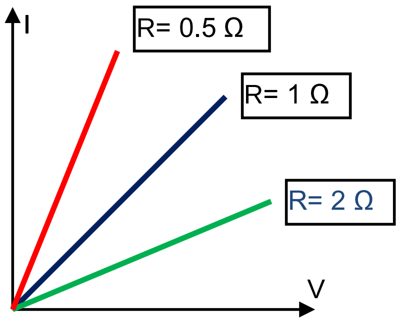
a) The higher the resistance, the lower the current.
b) The higher the resistance, the higher the current.
c) The lower the resistance, the higher the current.
d) The lower the resistance, the lower the current.

Activity 1d	Individual	unit2.pps (8,9)

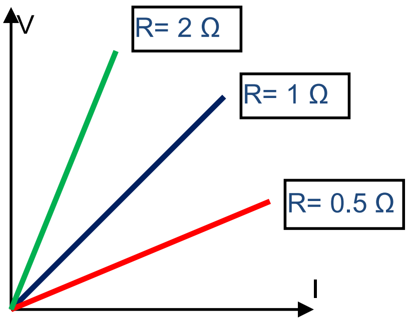
- Explain to students that graphs are **very** important to understand electronics.
- Show slide 8 and ask them to identify the resistor for each graph without calculations. They just have to apply the relationships they have learnt. You can suggest that they write down the formula that explains each graph (I=V/R and V=R·I).
- Ask some students describe the graphs for the whole class with the help of the substitution table and check at the same time the resistor values. Answers are on slide 9.

K1d In this circuit, R can be 0.5 Ω, 1 Ω or 2 Ω. Identify which resistance corresponds to each graph.





a)



b)

Construct a sentence that makes sense for graph a) and one for graph b).

a) The higher the resistance the lower the current for a given voltage.

b) The higher the resistance the higher the voltage for a given current.

The lower The higher	the resistance,	the lower the higher	the current the voltage	for a given	voltage. current.

Activity 2a	Individual	unit2.pps (10,11)

- Compare the use of multiples for resistance with the use of multiples for distance with m.
- Explain the examples and get students do the first part of the activity on slide 10.
- Check answers with slide 11. Check pronunciation for k and M.
- Focus on numbers first. Just when they manage the conversion you should move to writing numbers in the second part of the activity.

K2a Give the value in Ω for the following resistors.

a) 6k8 = 6,800 Ω
b) 1M2 = 1,200,000 Ω
c) 47R = 47 Ω
d) 5R6 = 5.6 Ω

Write the answers like this:
5M6: five point six mega-ohms are five million six hundred thousand Ω.

a) 6k8: six point eight kilo-ohms are six thousand eight hundred Ω.

b) 1M2: one point two mega-ohms are one million two hundred thousand Ω.

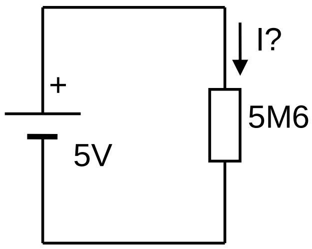
c) 47R: forty-seven Ω.

d) 5R6: five point six Ω.

Activity 2b	Individual, pairs.	unit2.pps (12, 13, 14, 15)

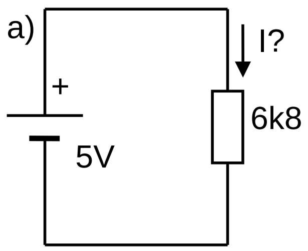
- Explain the submultiples of the Ampere. The distance example for m and mm usually works.
- Make students aware of the different use of . and , for grouping numbers and for decimal position in Anglo-Saxon countries.
- Let them do the calculations and check results or procedure with their partners. Remind them to be careful with the use of " ," or "." in their calculators.
- You or some student should do and explain the activity step by step on slides 12 and 13. You can use slides 14 and 15 to check results too.

K2b Now apply Ohm's law to calculate the current through the resistors as in the example. When you finish, check the answers with your partner without reading their workbook.

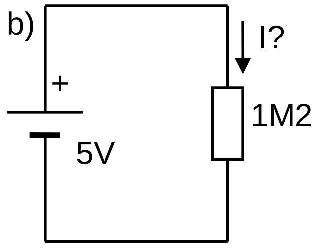


$$I = \frac{V}{R} = \frac{5}{5{,}600{,}000} = 0.00000089\ A = 0.89\ \mu A$$

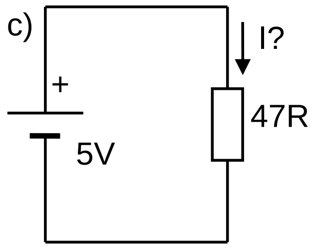
Remember: 0.001 A = 1 mA and 0.000001 A = 1μA



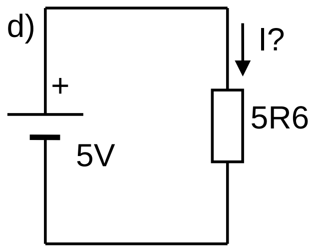
$$I = \frac{V}{R} = \frac{5}{6{,}800} = 0.000735\ A = 0.735\ mA$$



$$I = \frac{V}{R} = \frac{5}{1{,}200{,}000} = 0.00000416\ A = 4.16\ \mu A$$



$$I = \frac{V}{R} = \frac{5}{47} = 0.106\ A = 106\ mA$$



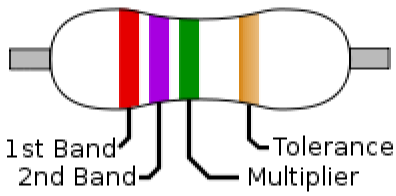
$$I = \frac{V}{R} = \frac{5}{5.6} = 0.893\ A = 893\ mA$$

What result did you get for part a)?

Activity 3a	Individual	unit2.pps (16, 17), some resistors

- Students should get the missing words from the table without further explanations. Just show them some resistors to see how the real colour code is printed on them. They will understand it better when they use it in the next activities.
- Read the text on slide 17 yourself or have some students to read it to check pronunciation.

K3a Fill in the blanks looking at the table below.



A lot of resistors have coloured rings on them instead of numbers. Each colour stands for a different unit: black is zero, brown is one, red is two; orange is three; yellow is four; green is five; blue is six; violet is seven; grey is eight; white is nine, as you can see in the table below.
The first band is for tens and the second band for units. The third band is the multiplier.

Example: red / violet / green stands for 2 / 7 / 00000, that is 2700000 Ω or 2.7 MΩ.

1st colour band			2nd colour band			Multiplier			Tolerance		
	Black	0		Black	0		Silver	divide by 0.01		Silver	10%
	Brown	1		Brown	1		Gold	divide by 0.1		Gold	5%
	Red	2		Red	2		Black	multiply by 1		Red	2%
	Orange	3		Orange	3		Brown	multiply by 10			
	Yellow	4		Yellow	4		Red	multiply by 100			
	Green	5		Green	5		Orange	multiply by 1,000			
	Blue	6		Blue	6		Yellow	multiply by 10,000			
	Violet	7		Violet	7		Green	multiply by 100,000			
	Grey	8		Grey	8		Blue	multiply by 1,000,000			
	White	9		White	9						

Activity 3b	Individual	unit2.pps (18,19)

- In this activity students are going to get the value of a resistor without the tolerance. It is quite easy for them just looking at the examples and at the colour table.
- Point out that colour black in the multiplier band means adding nothing.
- Early finishers can explain the code to those who have difficulties.
- Finally show slide 19 with the answers and read some values.

K3b Obtain the value of these resistors:

a) Brown / green / red: 1/5/00= 1,500 Ω = 1.5 kΩ
b) Orange / orange / brown: 3/3/0= 330 Ω
c) Green / grey / yellow: 5/8/0000= 580,000 Ω = 580 kΩ
d) Yellow /violet / orange: 4/7/000= 47,000 Ω = 47 kΩ

Express the previous values with M or k if possible. For example 27000 Ω= 27 kΩ

Activity 3c	Individual	unit2.pps (20, 21, 22)

- Explain the reasons for a tolerance band and how to calculate the maximum and minimum value for a resistor using slide 20.
- Now students have to calculate the maximum and minimum value for the four resistors in activity 3b. Remind them to be careful with the decimal point and not to forget the unit when they fill in the table on slide 21.
- Do some calculations for the whole class or show slide 22 with the answers.

K3c Manufacturers of the resistors cannot guarantee the exact value. The fourth band expresses the **TOLERANCE** in %. With the tolerance we can calculate the minimum and maximum real values for the four resistors below as in the example:

Red /violet / orange //silver R =27000 Ω ±10%
10% of 27000 = 27000·10/100=2700 R = 27000 Ω ± 2700 Ω
Minimum value =27000-270=26730 Ω Maximum value = 27000+270=27270

Colours	Value	Tol. %	Tol.	Minimum	Maximum
Red /violet / orange //silver	27000 Ω	10%	2700	26,730 Ω	27,270 Ω
Brown / green / red // silver	1500 Ω	10%	150	1,350 Ω	1,650 Ω
Orange / orange / brown // gold	330 Ω	5%	16.5	313.5 Ω	346.5 Ω
Green / grey / yellow // silver	580000 Ω	10%	58000	522,000 Ω	638,000 Ω
Yellow /violet / orange // gold	47000 Ω	5%	2350	44650 Ω	49,350 Ω

Activity 3d	Pairs	unit2.pps (23)

- Explain that resistor values come in preferred series values.
- Show them the activity and the sample dialogues for the activity on slide 23.
- Assess the groups as they produce the colour codes and dialogues.

K3d Work with your partner in turns. Choose 1 resistor from the pool and write down its colours. Then you have to tell your partner the colours and he has to find out the value.

1kΩ 680 kΩ 330 kΩ
1.5 kΩ 1.8 MΩ 2200 Ω
270 Ω
1.2 kΩ 8.2 kΩ
120Ω 270 kΩ
18 Ω
3.3 MΩ
390 Ω 820 Ω
4700 kΩ 5.6 kΩ 47 kΩ

- My resistor is brown, black, red.
- Yes, it is. You are right…

- Is it 1000 Ω?
- My resistor is …

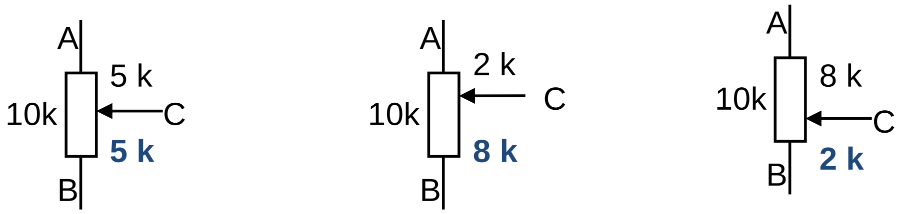
Activity 3e	Individual or pairs, class	unit2.pps (24), real resistors

- This is a summary activity on resistors. Show students slide 24 with the model for describing a real resistor. Students can work individually or in pairs.
- When they finish ask a few of them one by one to describe the resistor. The rest of the class must check the answer and report if they find any mistake. You can use this activity for assessment.

k3e Your teacher will give you one real resistor. Note down the colours, calculate its value and write the text to describe your resistor to the class.

Activity 4a	class	unit2.pps (25,26), some potentiometers
• Explain how potentiometers are and work using some real ones. • Do the activity orally with the whole group to check understanding. Answers are on slide 26. • Make them copy results into their workbook.		

K4a Can you get the values for R_{CB} in these 10 kΩ potentiometers?



Activity 4b	Individual	unit2.pps (27, 28, 29)
• Show slide 27 with the special resistors table. Explain what “coefficient” means using the language students learnt for Ohm’s law: the higher, the lower... • Show activity on slide 28. Let them write the explanations for PTC and LDR. • Have some of them read their answers and compare results with slide 29.		

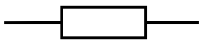
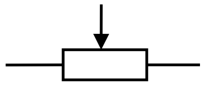
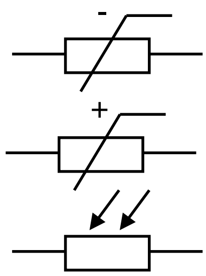
K4b Explain how the special resistor works as in the model:

- NTC thermistors’ resistance changes according to the temperature. As temperature goes up, the resistance goes down. They are used in temperature-sensing circuits.
- PTC thermistors resistance changes according to the temperature. As temperature goes up, the resistance goes up. They are used in temperature-sensing circuits.
- LDR’s resistance changes according to light. As light is brighter, the resistance goes down. They are used in light-sensing circuits.

Activity 4c	Individual	unit2.pps (30,31)

- Show empty diagram on slide 30. Let students fill in the blank from their knowledge or look for the names from previous activities.
- Use slide 31 in combination with previous slides to show the finished diagram and where information is. You can round-up with some questions as
  - What's the difference between a fixed resistor and a potentiometer?
  - What's the difference between the symbol of a LDR and a variable resistor?

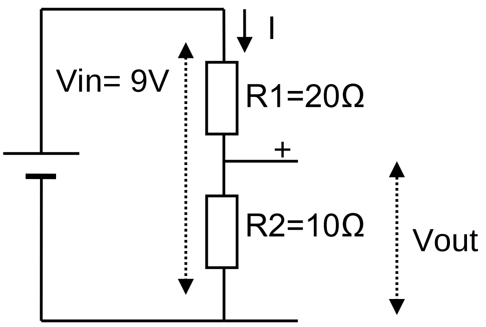
K4c Complete the visual organizer.

Resistors
- Fixed resistors.

- Variable or potentiometers.

- Special resistors
  - NTC thermistors
  - PTC thermistors
  - LDR's


Activity 5a	Individual	unit2.pps (32, 33, 34)

- Explain how and why we use resistors in potential dividers with slide 32.
- I suggest deducing the formula to review Ohm's law and series resistor association.
- Use slide 32 to show the voltage divider they have to solve. Preferably, they have to do it without a calculator.
- The key is on slide 34.

K5a Calculate Vout by applying the formula of a voltage divider.

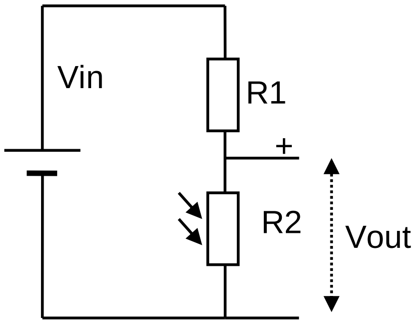


$$Vout = 9 \cdot \frac{10}{20+10} = 9 \cdot \frac{1}{3} = 3\,V$$

Activity 5b	Individual	unit2.pps (35,36)

- Show slide 35 and let students predict the effect of the LDR on the output voltage.
- Check answers with slide 36.
- You can finish by asking what would happen if we swapped R1and R2 in the circuit.

K5b When one of the resistors is a special resistor the circuit is a sensor. Predict how light changes will affect Vout.



cause	Light goes down	Light goes up
effect / cause	R2 goes **up**	R2 goes **down**
effect	Vout goes **up**	Vout goes **down**

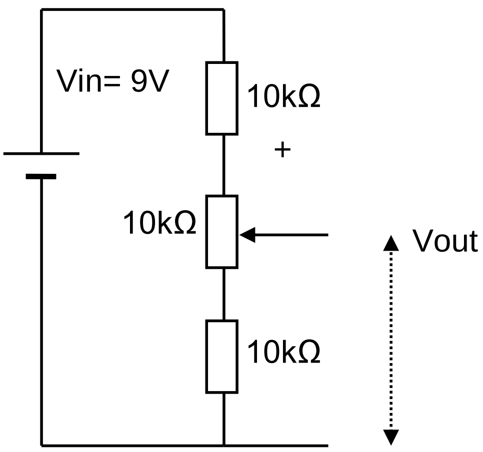
Prepare to answer questions like

- What is the effect of light going down? *If light goes down, Vout goes up*.
- What is the cause of Vout going up? *Vout goes up if light goes down*.

Activity 5c	Individual	unit2.pps (37, 38)

- This activity requires full understanding of variable resistors and voltage dividers.
- Let students try to solve the problem on slide 37 without any help and preferably without calculator. Probably, only the more able students will do it. Give clues progressively until all of them can do it.
- Check answers with slide 38.

K5c Calculate the minimum and maximum values of Vout that we can get by adjusting the potentiometer.



Cursor **at the top end**: R1=10k and R2=20k

$$Vout = 9 \cdot \frac{20}{20+10} = 9 \cdot \frac{2}{3} = 6\,V$$

Cursor **at the bottom end**: R1=20k and R2=10k

$$Vout = 9 \cdot \frac{10}{20+10} = 9 \cdot \frac{1}{3} = 3\,V$$

2.2 Capacitors.

1 h	Classroom	unit2.pps, some real capacitors

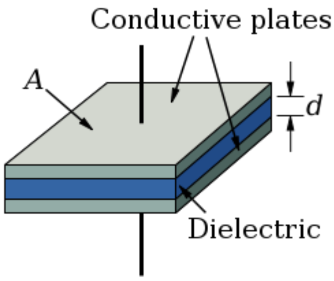
Activity 6a	Individual	unit2.pps (39, 40), u2a6a.mp3

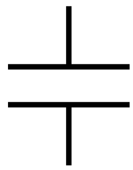
- Let students read the gapped text on slide 39 and try to guess the missing words.
- Read or play the audio file of the text. Check answers with slide 40.
- Show them some real capacitors. Explain the analogy with a water tank that can be filled and emptied of water instead of electrons.
- Point out that capacitors can take up quite a lot of space in a circuit and that new technologies try to avoid using them, at least the bigger ones.

K6a Listen and fill the gaps in this text about capacitors.

A capacitor is a discrete component which can store an electrical charge. The larger the *capacitance* *the more* *charge* *it can store.*

Capacitors are used in *timing* *circuits, to filter* *signals* *and as* *sensing* *devices.*





Symbol

Activity 6b	Individual	unit2.pps (42, 43)

- Explain the conversion table between the Farad and its submultiples. You might anticipate some difficulties with the use of scientific notation and need to explain this.
- Show students how to say for example $5 \cdot 10^6$: five times ten to the power of 6.
- Give them time to do the conversions. Then ask some of them to read the results. Check with slide 43.
- Propose some more repetition work if necessary.

K6b The unit of capacitance is the Farad. As this is a large amount, these submultiples are used:

micro-Farad (µF)	nano-Farad (nF)	pico-Farad (pF)
$1\mu F = 10^{-6}$ F	$1nF = 10^{-9}$ F	$1p F = 10^{-12}$ F
1µF = 0.000001 F	1nF = 0.000000001 F	1p F = 0.000000000001 F
1 F= 1,000,000 µF = 1,000,000,000 nF = 1,000,000,000,000 pF		

Convert these values to Farads as in the example. Check answers with your partner.

Example) 33 nF = *0.000000033 F* = $33 \cdot 10^{-9}$ *F*

a) 100 pF = 0.0000001 F = $100 \cdot 10^{-9}$ F

b) 10 µF = 0.00001 F = $10 \cdot 10^{-6}$ F

c) 0.1 µF = 0.0000001 F = $100 \cdot 10^{-9}$ F

d) 68 nF = 0.000000068 F = $68 \cdot 10^{-9}$ F

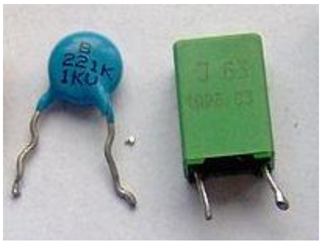
Activity 6c	Pairs	unit2.pps (44, 45)
• Show slide 44. Let students read the text and discuss the answers with their partners. Let them guess the last question. • Check answers with slide 45. Explain why electrolytic capacitors have a minus sign on them and that it is very important not to invert polarity or to surpass the maximum voltage because they literally explode.		

K6c Read the text and then answer the questions below.

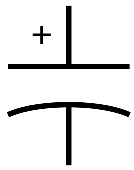
The small capacitance capacitors are made of polyester (nF) and ceramic (pF).

For large capacity values (µF) electrolytic capacitors are used. These are polarised and marked with the maximum voltage.

Be careful not to connect electrolytic capacitors the wrong way or across a higher voltage.



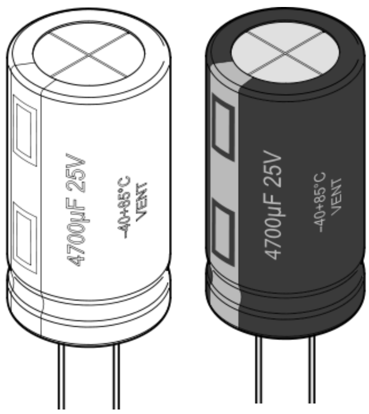
Ceramic and plastic capacitors



Polarised capacitor symbol

What kind of capacitor is this?

It's an electrolytic capacitor.



Describe its characteristics?

Its value is 4700 µF.

Its maximum voltage is 25 Volts.

It can work between -40° and 85 °C.

Discuss with your partner what will happen if we use them in a 50V circuit?

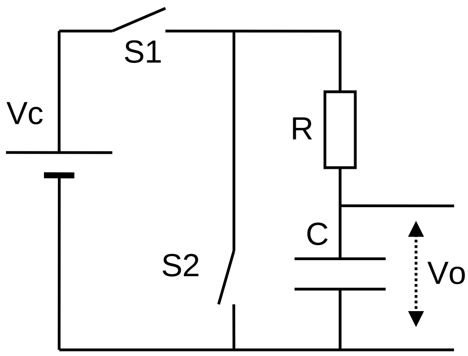
I think it will explode

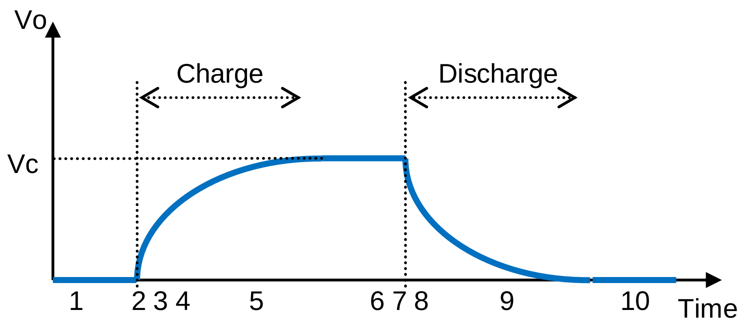
because it can only stand 25 V.

Activity 7a	Individual	unit2.pps (49, 50)

- Explain the charge and discharge graph of a capacitor on slide 49. Stress the language used to describe graphs.
- You can compare it with a water tank. The resistance can be the water valve and the voltage the water level from where it fills or to where it empties.
- Let students sequence the actions. Do one or two together as an example.

K7a Usually we connect a capacitor in series with a resistor for timing purposes. The flow of current through a resistor into the capacitor charges it until it reaches the same voltage than the power supply. Analyse the diagrams and try to sequence the text with your partner putting order numbers in the empty cells.





A	The capacitor starts discharging sharply through R.	**8**
B	S1 is switched off and S2 is switched on.	**7**
C	At the beginning switch 1 and 2 are off.	1
D	The capacitor starts charging fast through R.	**3**
E	The capacitor is fully discharged.	**10**
F	S1 is switched on.	**2**
G	Vo rises slowly as it approximates Vc.	**5**
H	The capacitor is fully charged at Vc.	**6**
I	The voltage across the capacitor rises sharply.	**4**
J	Vo decreases slowly as it approaches 0V.	**9**

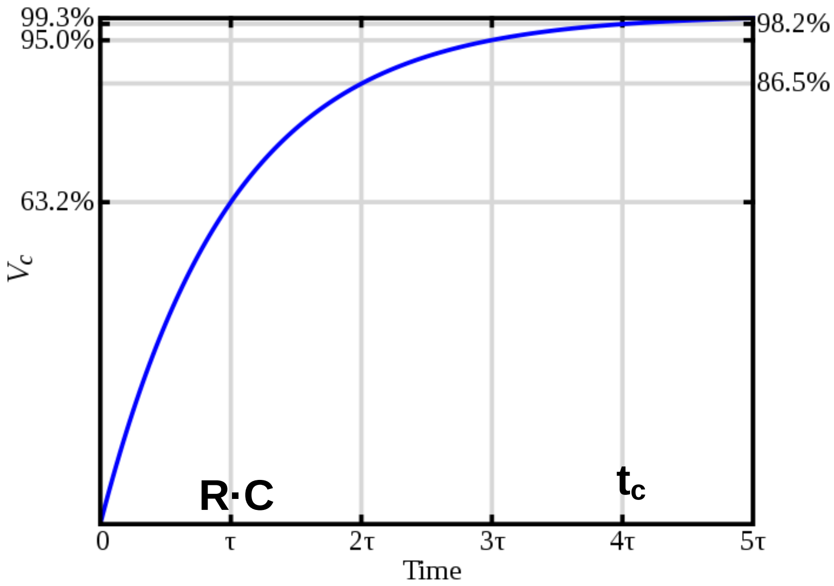
Activity 7b	Individual	unit2.pps (49, 50, 51)

- Show the graph on slide 49 to explain how we can calculate the time it takes to charge a capacitor.
- Let students answer questions on slide 50 before checking with slide 51.
- Ask some more questions orally to the class such as "What will happen if we double both?"

K7b The time it takes to charge a capacitor depends on a time constant called tau. Tau depends on the resistor and the capacitor. The total charging time (**t_c**) is approximately 4 times this time constant.

$$\tau = R \cdot C$$

$$t_c = 4\,\tau$$



a) What % of the final voltage does the capacitor reach after τ? And after 4τ?
After τ seconds the capacitor reaches 63.2% of Vc.
After 4τ seconds, the capacitor reaches 98.2% of the final voltage.

b) Calculate the time constant for R=100 kΩ and C=100μF.
$\tau = R \cdot C = 100{,}000 \cdot 0.0001 = 10$ seconds

c) What happens to the charging time if we halve the value of the resistor?
We can predict that the time constant will be half of 10 seconds.
$\tau = R \cdot C = 50{,}000 \cdot 0.0001 = 5$ seconds

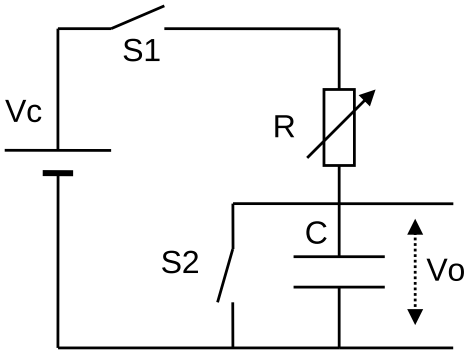
d) What happens to the charging time if we double the value of the capacitor?
We can predict that the time constant will be the double of 10 seconds.
$\tau = R \cdot C = 100{,}000 \cdot 0.0002 = 20$ seconds

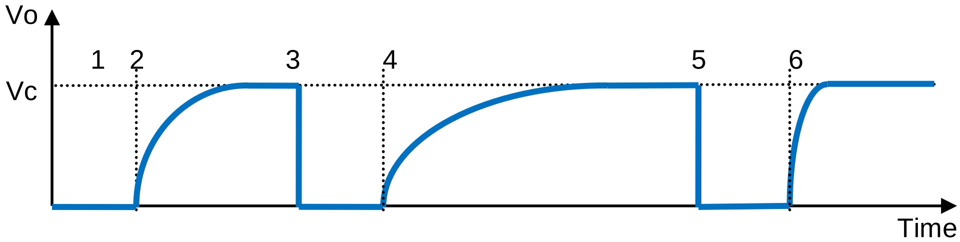
Activity 7c	Individual	unit2.pps (52, 53)

- Show circuit on slide 52. Make students notice that when we switch on S2 the discharge resistance is 0 and that the charging resistor can be varied.
- Put them to work in pairs to understand the circuit and to write a sequence of actions as in activity 7a.
- If this is too difficult, break down the task into small steps and correct action by action. A possible description of the sequence is on slide 53.

K7c This circuit is similar to that of activity 7a. Note that this time R is adjustable. Explain what actions the following graph describes. Pay special attention to what happens between 3 and 4, and between 5 and 6.

When you finish discuss your results with your partner.





At the beginning, S1 and S2 are off. The capacitor is not charged.

At instant 2, switch 1 is turned on. The capacitor starts charging fast through the resistor. Before instant 3 the capacitor is fully charged. At that moment S2 is switched on and the capacitor discharges instantly because there is no resistance.

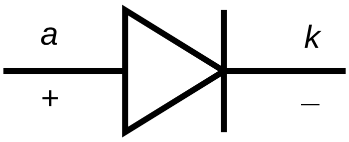
Between 3 and 4 the resistance is adjusted to a higher value. At instant 2 S2 is switched off again and the capacitor starts charging slowly through the new R. It reaches Vc and stops charging until S2 is switched on again at instant 5. Then the capacitor discharges again.

B Between 5 and 6 the resistance is adjusted to a lower value. At instant 6 S2 is switched off again and the capacitor charges faster this time because of the low resistance.

2.3 Diodes.		
1 h	Classroom	unit2.pps, some real diodes

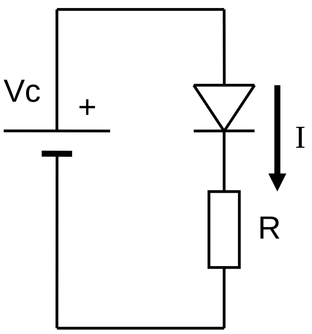
Activity 8a, 8b	Individual	unit2.pps (54, 55, 56)
• Introduce diodes with slide 54. Show some real diodes. You can ask students when the semiconductors were invented to link content to unit 1. • Students answer questions on slide 55. Answers are on slide 56.		

Semiconductors are materials that conduct electricity under certain conditions. Silicon is the most used to make electronic components.

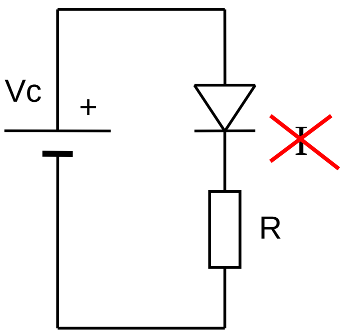


symbol

Forward bias



Reverse bias



A diode is a semiconductor device that allows current to flow in one direction. It can be used for protection, to block signals, to change AC to DC, etc.

The two leads are called anode (a or +) and cathode (k or -).

K8a Look at the diagrams above and fill in the blanks.

The current can only flow from anode *to* cathode*. This direction is called* forward *bias.*

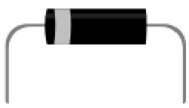
The current cannot flow from cathode *to* anode*. This direction is called* reverse *bias.*

K8b The cathode is identified by a band on its body. Label the leads of these diodes as anode or cathode.

anode

cathode

cathode

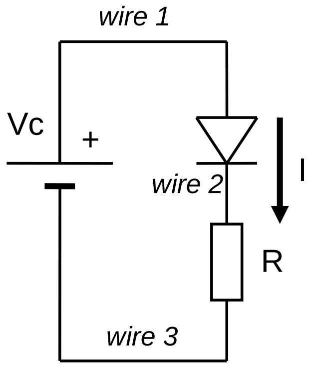


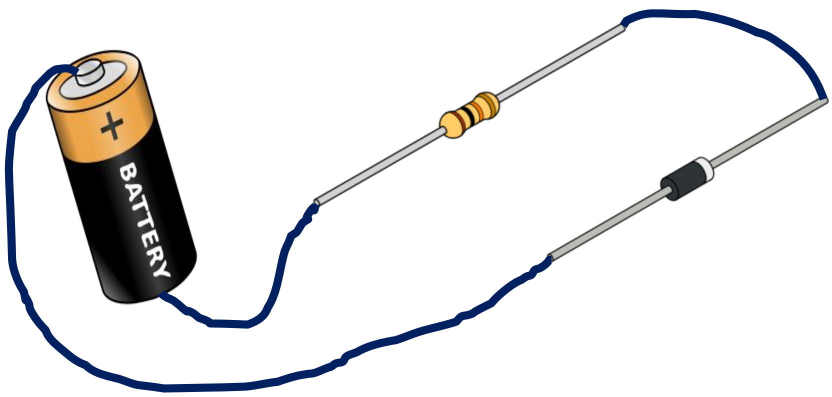
anode

Activity 8c	Pairs	unit2.pps (57, 58)

- Show circuit on slide 57 with isolated components. In pairs, students have to connect the components and describe the connections.
- Assess the group and choose one student (or more) to do it at the IWB for all the class.
- You can show a model answer on slide 58.

K8c Draw wires to connect this diode in direct biasing as seen in the circuit diagram.





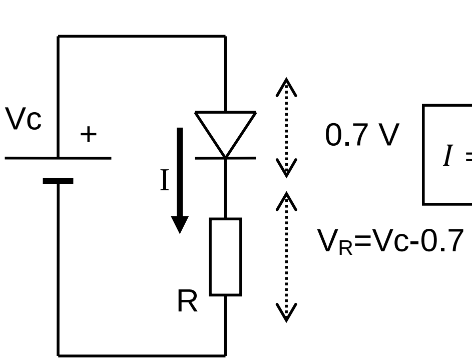
Explain to your partner how you have connected the wires:

The first wire goes from positive lead of the battery to the anode of the diode. The second wire goes from the cathode of the diode to a lead of the resistor. The third wire goes from the other terminal of the resistor to the negative pole of the battery.

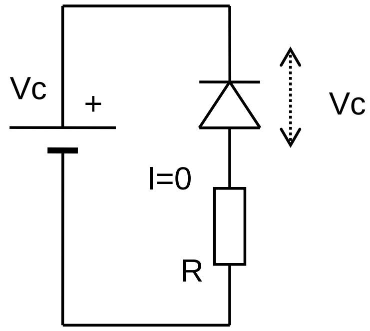
Activity 9	Individual, pairs	unit2.pps (59, 60, 61)

- Deduce and explain the formula to calculate the forward bias current through a diode on slide 59.
- Students have to calculate the current for the 3 circuits. The third one has two diodes in series. They will have to deduct the new formula.
- Make them check in pairs and practise the maths language: “divided by” , “minus”, “equals”, “over”...
- You can show the calculations on slide 61.

The voltage needed to operate the diode in forward bias is about 0.7 V. Here you can see how to calculate the current in forward bias.

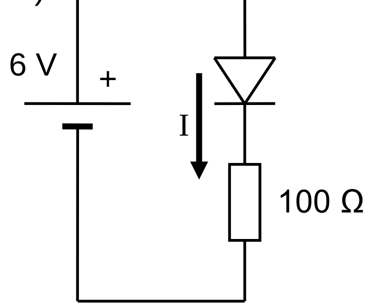


$$I = \frac{V_R}{R} = \frac{Vc - 0.7}{R}$$



K9 Calculate the current (I) in these 3 circuits.

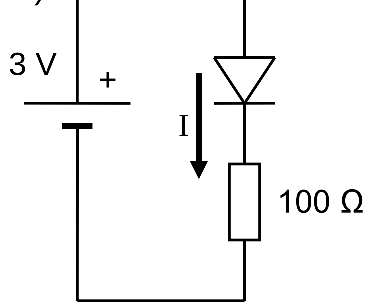
a)



$$I = \frac{V_R}{R} = \frac{Vc - 0.7}{R}$$

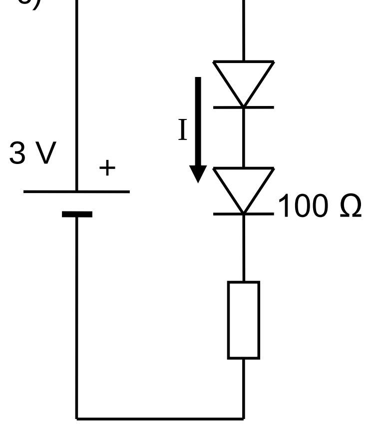
$$I = \frac{6 - 0.7}{100} = \frac{5.3}{100} = 0.053\ A = 53\ mA$$

b)



$$I = \frac{3 - 0.7}{100} = \frac{2.3}{100} = 0.023\ A = 23\ mA$$

c)

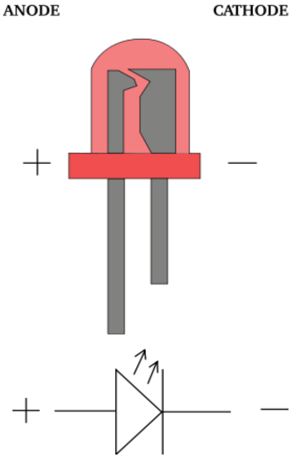


$$I = \frac{3 - 0.7 - 0.7}{100} = \frac{1.6}{100} = 0.016\ A = 16\ mA$$

Activity 10	Individual	unit2.pps (62, 63, 64), real LEDs

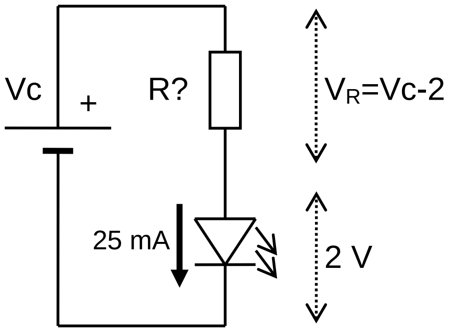
- Show slide 62 to explain what an LED is. Show students some LEDs and ask them where LEDs are used. You can explain that LEDs have a bright future in lighting applications because of their long life and low consumption.
- Students should solve the problems on slide 63 individually. Answers are on slide 64.

Light-emitting diodes or **LEDs** are made from different semiconductor materials that give off light when connected in forward biasing.



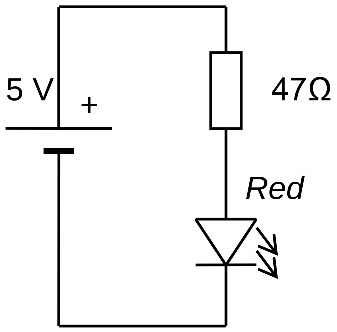
The forward bias voltage can be between 1.6 V and 3.5 V depending on the colour (2 V for red colour).

Usually an LED is connected in series with a resistor to limit the current between 20 mA and 30 mA. More current would fuse it. You can see the usual circuit and the equations below to calculate the current or the resistor value.



$$I = \frac{V_R}{R} = \frac{Vc - 2}{R}$$

$$R = \frac{V_R}{I} = \frac{Vc - 2}{I}$$



K10 Is the LED in the circuit safe? No, it isn't. Why (not)? Because the current is 64 mA and it must be between 20 mA and 30 mA.

$$I = \frac{V_R}{R} = \frac{Vc - 2}{R} = \frac{5 - 2}{47} = 0.064\ A = 64\ mA$$

Calculate the resistor value to set the current to 30 mA.

$$R = \frac{V_R}{I} = \frac{Vc - 2}{I} = \frac{5 - 2}{0.030} = \frac{3}{0.03} = 100\ \Omega$$

Calculate a new resistor value to set the current to 20 mA.

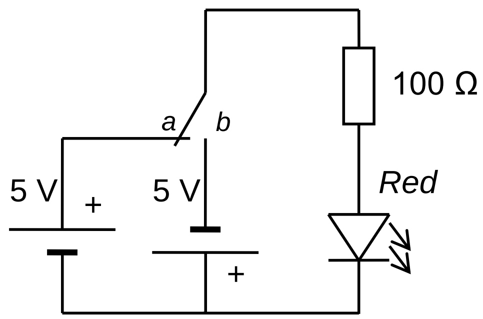
$$R = \frac{V_R}{I} = \frac{Vc - 2}{I} = \frac{5 - 2}{0.020} = \frac{3}{0.02} = 150\ \Omega$$

Activity 11a	Individual	unit2.pps (65, 66)

- Students have to discuss the circuit and complete the sentences in slide 65.
- You may need to explain how the double pole switch works.
- All the answers are on slide 66 but first do the text for position "a" so that it can be used as an example for position "b".

K11a Look at the circuit and answer these questions. You can ask them to your partner.

- Will the LED glow when the switch is at position "a" ?
- Yes it will because it is forward biased.
- What will the voltage across the resistor be?
- It will be 5-2 = 3 Volts



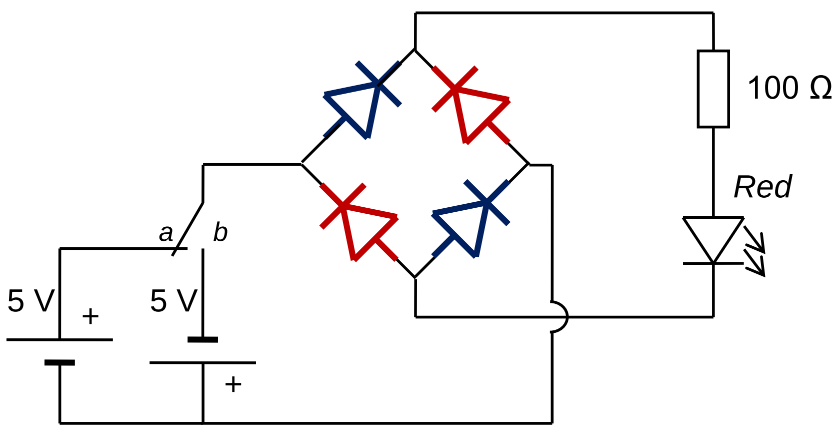
- Will the LED glow with the switch at position "b" ?
- No it won't because it is reverse biased.
- What will the voltage across the resistor be?
- It will be 0 Volts.

Activity 11b	Individual, pairs.	unit2.pps (67, 68)

- Students have to finish a design to convert AC to DC. Show the incomplete schematics circuit on slide 67. Make sure they understand the instructions.
- Give some help if needed, for example place one diode, then wait, after a while place one more, and go on like this. If some students finish early get them to help some less able students.
- Answers are on slide 68. You can ask some students to explain the path that the current follows in each position of the switch.

11b The following circuit is a bridge rectifier. It is widely used to convert AC into DC.

a) Place 3 more diodes in the circuit so that the LED glows in both positions of the switch. Draw in blue the two diodes that conduct when the switch is at position *a*. Draw in red the ones that conduct in position *b*.



b) What will the current through the through the resistor be?

$$I = \frac{V_R}{R} = \frac{Vc - 0.7 - 0.7 - 2}{R} = \frac{5 - 3.4}{100} = \frac{1.6}{100} = 0.016\ A = 16\ mA$$

2.4 Transistors.		
1 h	Classroom	unit2.pps, transistors, u2.mp3

Activity 12a	Individual	unit2.pps (69, 70, 71, 72), transistors, u2a12a.mp3

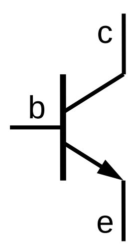
- Start with some oral question so students review what they learnt about transistors in unit 1.
- Give them time to read the text (slides 69, 70). Work on the vocabulary if necessary.
- Read the text or play the audio file one or two times. Check missing words with slides 71 and 72.
- Explain that there are more types of transistors but that all of them are used to amplify or to switch.

K12a Listen to the text and fill in the blanks.

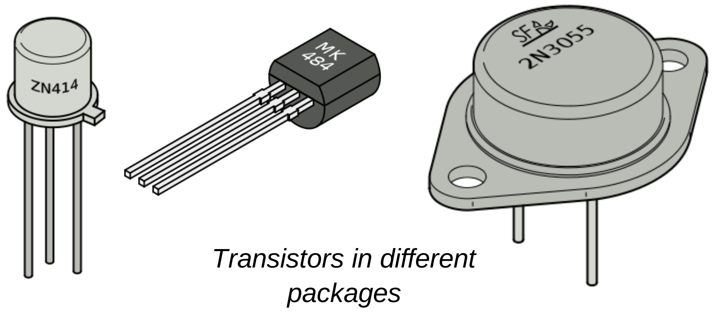
A transistor is a semiconductor device used to amplify and switch electronic signals. We will focus on the common NPN bi-polar type of transistors.

It has terminals for connection to an external circuit. The three leads are:

- *The base (b), which is the lead responsible for activating the transistor.*
- *The collector (c), which is the positive lead*
- *The emitter (e), which is the negative lead.*



NPN bi-polar transistor symbol

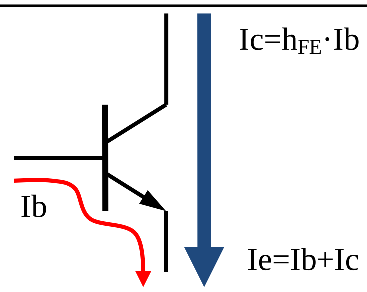


Transistors in different packages

When a small current flows through the base-emitter circuit, a much larger current flows through the collector-emitter circuit.

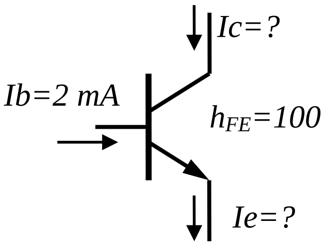
$$Ic = h_{FE} \cdot Ib$$

The gain (h_{FE}) is the amount by which the transistor amplifies current. Usual values are around 100.



Activity 12b	Individual	unit2.pps (73,74)
• Use the example to explain how to calculate Ic from Ib, and Ie from Ib and Ic. • Let students do the activities on their own. For activity c) they will need to do a math transformation to the basic formula. Some might need help. • Answers are on slide 74.		

K12b Calculate the Ib and Ie for the given Ib and h_{FE} as in the example.



$$Ic = h_{FE} \cdot Ib = 100 \cdot 2mA = \mathbf{200\ mA = 0.2\ A}$$
$$Ie = Ib + Ic = 2 + 200 = \mathbf{202\ mA = 0.202\ A}$$

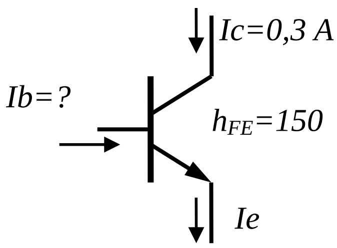
a) Ib=0.1 mA; h_{FE}=80

$$Ic = h_{FE} \cdot Ib = 80 \cdot 0.1mA = \mathbf{8\ mA = 0.008\ A}$$
$$Ie = Ib + Ic = 0.1 + 8 = \mathbf{8.1\ mA = 0.0081\ A}$$

b) Ib=12 mA; h_{FE}=120

$$Ic = h_{FE} \cdot Ib = 120 \cdot 12mA = 1440\ mA = \mathbf{1.44\ A}$$
$$Ie = Ib + Ic = 12 + 1440 = 1452\ mA = \mathbf{1.452\ A}$$

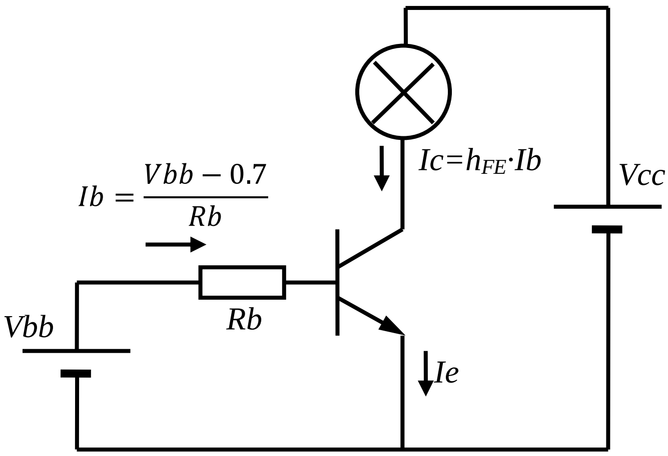
c) Can you calculate the Ib that we need to get Ic=0,3A if h_{FE}=150?



$$Ib = \frac{Ic}{h_{FE}} = \frac{0.3}{150} = 0.002A = 2\ mA$$

Activity 12c	Individual	unit2.pps (75,76)
• Use slide 75 to explain how to calculate the base current. It is exactly the same as what they did in order to calculate the forward current through a diode. • Get students to solve the circuit. The result is on slide 76. • Ask the class what will happen if we halve Rb to introduce next activity.		

K12c As with diodes, a voltage of 0.7V is necessary across the base-emitter to activate the transistor. In this circuit you can see the formula to calculate the current into the base. Then you can calculate the current into the collector.



Find out Ib and Ic for these values:
a) Vbb=3V; Rb=100Ω; h_{FE}=100

$$Ib = \frac{3 - 0.7}{100} = \frac{2.3}{100} = 0.023\ A = 23\ mA$$
$$Ic = 100 \cdot 0.023A = 2{,}3\ A$$

Activity 13a	Individual	unit2.pps (77, 78)

- Put students to work in pairs. They have to discuss on the cause-effect relationships in the circuit using the substitution table. Get them to talk for a while before they write.
- Listen to some of the answers. You can show slide 78 for sample answers.

K13a Discuss with your partner and find two ways to make the light bulb glow brighter in the last circuit.

If we increase/decrease Vbb If collector current goes up/down If base current goes up/down	then	base current will go up/down the light bulb will glow brighter /dimmer collector current goes much higher/lower.

a) One way to make the light bulb glow brighter is to increase *Vbb* because then *the base current will go up. As a result the collector current will go much higher and the light bulb will glow brighter.*

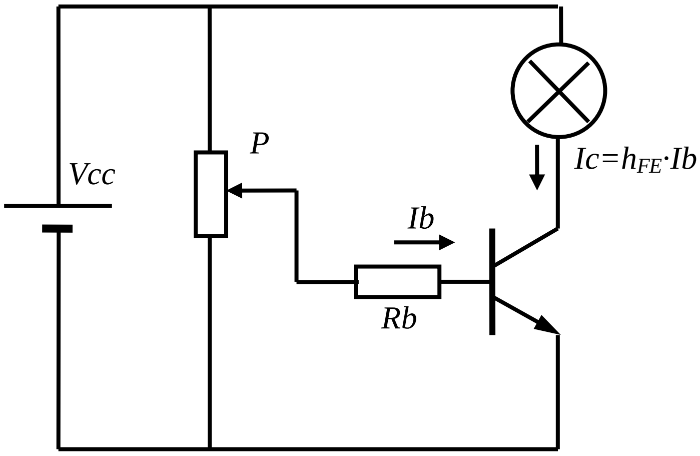
b) Another way to do it is *to lower the resistance value of Rb.*

Activity 13b	Individual	unit2.pps (79, 80)

- Before explaining how the circuit works, let students guess. Show slide 79 with the circuit and ask them to match the sentence beginnings with the endings.
- As you correct the activity explain the circuit. You can use the matched sentences on slide 80. Talk about possible applications, for example to amplify audio or other analogue signals.

13b In this circuit the transistor works as a **CURRENT AMPLIFIER**.

Match sentence beginnings with endings.



1. The potentiometer............................
2. Moving the cursor up is like..............
3. To make the light bulb glow dimmer..
4. The collector current is controlled......

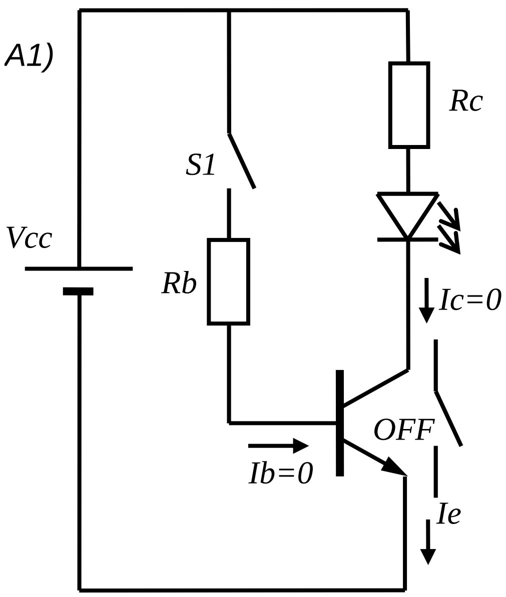
c) works as a potential divider.
d) making Vbb higher in exercise 12a.
a) you have to move the cursor down.
b) by the potentiometer.

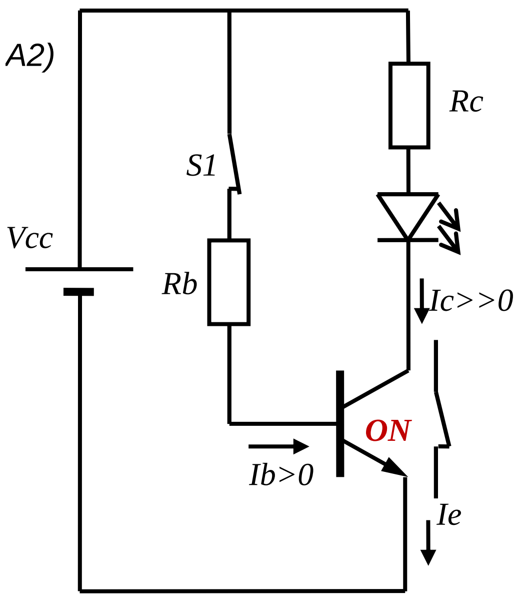
Activity 14a	Individual or pairs	unit2.pps (79, 80)
• Give students time to try to understand how the circuits A and B work and identify the circuits in the activity. You may pair some less confident with more able ones to discuss it. • Go through the answers on slide 80 to explain the circuits. • Ask some students to try to explain what happens in both circuits when the switch is OFF.		

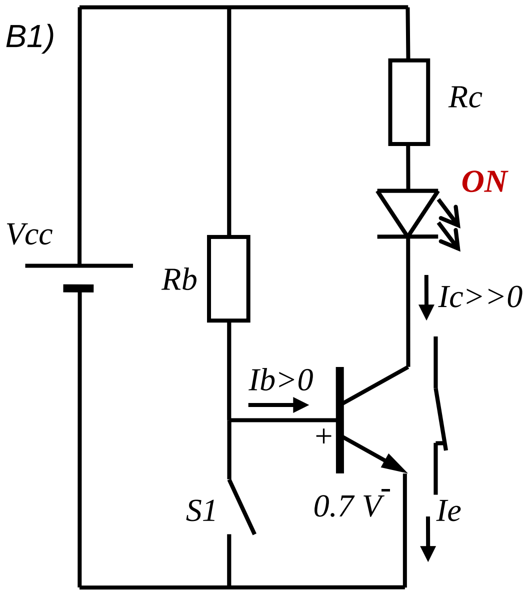
In many cases we don't need to control the collector current in a continuous analogue way. We just want 2 states. It works as a **DIGITAL SWITCH** controlled by the base current:

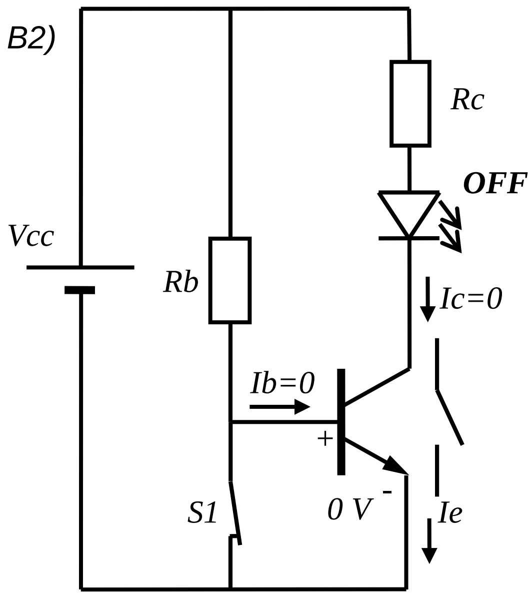
a) OFF: Ic=0 because Ib=0 or voltage across base-emitter is lower than 0.7 V.
b) ON: Ib is the maximum possible in the circuit because Ic is high

K14a Look at circuits A and B and identify which circuit the two descriptions refer to.







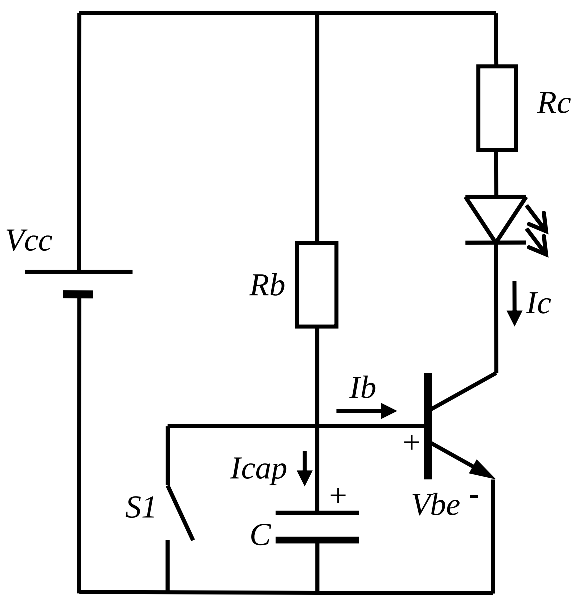


A: When the switch is ON a current passes through the resistor into the base of the transistor. Then the transistor allows collector current to flow and the LED comes on.

B: When the switch is ON the voltage across base-emitter comes to 0. Then the transistor doesn't allow collector current to flow and the LED goes off.

Activity 14b	Group, individual	unit2.pps (84,85)
• Show the circuit on slide 84. Ask questions to the class to guide them to understand it. For example: "S1 is on, what is the voltage Vbe? –And what will Ib be? –So, what will the Ic be? –Will the LED glow?..." Then get them to write it in the activity, bit by bit. • Finally you can check the whole text with slide 85.		

14b In this circuit the transistor also works as a SWITCH. The capacitor charges through Rb. Rb and C form a voltage divider for timing purposes. Try to predict how the circuit works.



When S1 is on *the voltage across base-emitter comes to 0. Then the transistor doesn't allow collector current to flow* and the LED is *off.*

When S1 is off the capacitor *starts charging through Rb* and the LED is *off.* When voltage across the capacitor reaches *0.7* V *current passes through the base, collector current flows* and the LED is *on* until *S1 is switched on again.*

Self assessment Students have to reflect on what they have learnt. Show slide 86 and tell them that they should review the parts of the lesson where they don't answer yes.

QUESTION	No	More or less	Yes
Can I get the value of a resistor using the colour code and use multiples to express it?			
Can I list the different types of resistors, draw their symbols and explain possible applications?			
Can I calculate voltage in simple voltage dividers?			
Can I describe and calculate charge and discharge of a capacitor in RC circuits?			
Can I calculate currents in circuits with diodes and resistors?			
Can I explain how a transistor works in a circuit, both as a switch or as an amplifier?			
Can I interpret diagrams and identify components to build simple circuits?			

2.5 Building real circuits.

3 h	Workshop / pairs	unit2.pps, analogue kit

The teaching notes for this practice work are quite open because every teacher will have to adapt the work according to the material and equipment in their schools. The language support is going to depend much on whether the students have done previous electricity activities in the workshop.

I suggest building three tested circuits with very common components on a breadboard. You can power the circuits with a 4.5 V battery or with a power supply.

Before starting with the circuits, check if students need to work on these points:

- New vocabulary: breadboard, leads, screwdriver, strips, multimeter... You can use this website: http://www.kpsec.freeuk.com/
- Safety rules.
- How to use a multimeter. (http://tipdeck.com/how-to-use-multimeter)
- Making connections on a breadboard.

I propose that students work in pairs and follow this procedure:

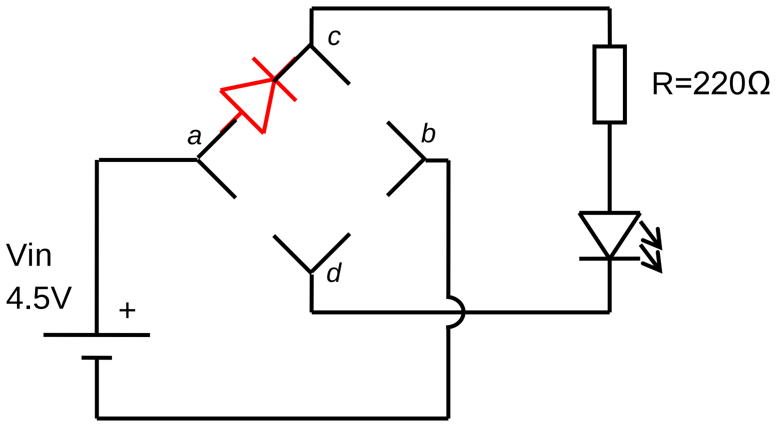
- Explain to students the rubric for assessment.
- Students have the schematics diagrams but don't have the component values. To force communication you can stick the complete schematics on a wall and do a sort of a running dictation. Alternatively you can just dictate the values.
- Do some **demonstrations** to build the circuit and some measurements. Ask some initial questions to make sure that everybody understands the circuit.
- Give out the components and the equipment.
- Let them build the circuit and take measurements. Collaboration within and between the groups should be encouraged.
- Once the circuit is running, you can give them some more extra tasks: some measurements, calculations, modifications to the circuits...
- Early finishers can help other groups or maybe they can prepare an oral summary of the practical.
- Assess the work with the students.

In order to assess the practical work I suggest using this simple rubric.

	Fail	Developing	Good
I understand the circuit, can identify the components and make the circuit work.	0	2	4
I respect the rules and build the circuit in a neat way.	0	1	2
I can collaborate with my partner and with other groups.	0	1	2
I use English to communicate during the task.	0	1	2

2.5.1 Rectifier bridge.

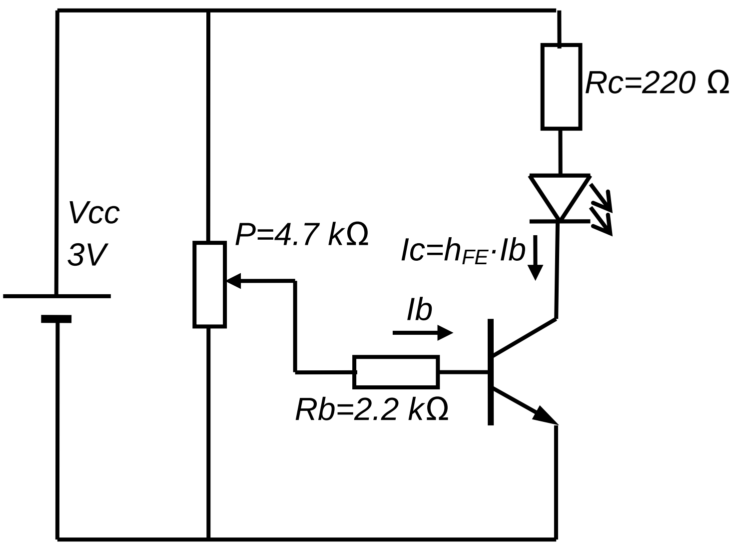
With this circuit students can practise with forward and reverse biased diodes. You can find the diagram in the unit2.pps, without values on slide 88 and with the values on slide 88.



- Possible previous questions: calculate R, get the resistor colours, identify the anode and the cathode of the diodes...
- Possible measurements: voltage across the components, current through the LED...
- Possible extra-work: change the LED colour, invert polarity of the voltage supply...

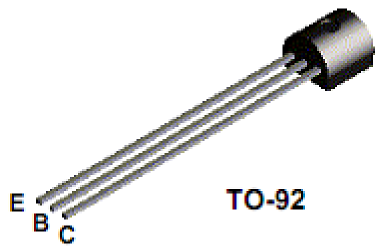
2.5.2 Light regulator.

This circuit allows students to experiment with a voltage divider and a transistors working as a current amplifier. The diagrams are on slides 89 and 90.



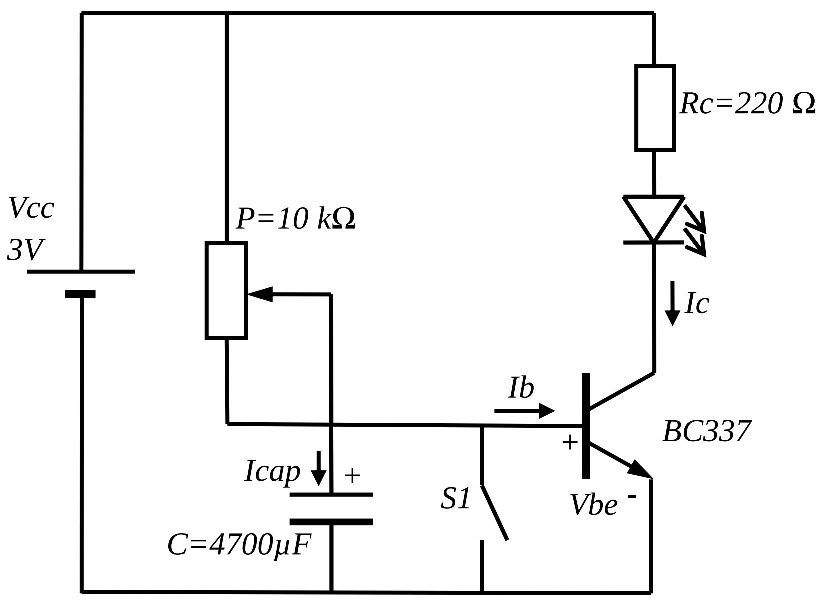
- Possible previous questions: calculate the maximum base current, get the resistor colours, identify the three terminals of the transistor...
- Possible measurements: base current and collector current for different positions of the potentiometer, obtain the real h_{FE} from measured Ib and Ic ...
- Possible extra-work: draw a Ic/Ib plot, analyse the BC337 datasheet from the internet...

BC 337 lead identification:



2.5.3 Timer.

This circuit allows students to experiment with an RC timing circuit and a transistor working as a switch. The diagrams are on slides 91 and 92.



- Possible previous questions: calculate the minimum and maximum time constant, predict circuit function with graphs...
- Possible measurements: capacitor voltage change, base-emitter activation voltage, collector-emitter saturation voltage...
- Possible extra-work: modifications to achieve longer or shorter timings...

3 DIGITAL ELECTRONICS.

4 h	Classroom, computer room	unit3.pps , w/s A/B, computers+software

Slides for unit 3:

1. Title.
2. 1: binary system and switches.
3. 1: answers.
4. 2a: binary from 1 to 16.
5. 2a: answers.
6. 2b: convert binary to decimal.
7. 2b: answers.
8. 2c: convert decimal to binary.
9. 2c: answers.
10. Example of binary addition.
11. 3a: binary additions.
12. 3a: answers.
13. Introduction to Boolean logic.
14. 4a: Boolean operators.
15. 4a: answers.
16. Gates and truth tables.
17. 4b: inverter, and gates.
18. 4b: answers.
19. 4b: or, nand gates.
20. 4b: answers.
21. 4b: nor, xor gates.
22. 4b: answers.
23. 4c: gate symbols description.
24. 4d: logic Venn diagrams.
25. 4d: answers.
26. Gates with electrical switches.
27. 5: gates with transistors.
28. 5: answers.
29. 6a: simple logic circuit.
30. 6a: answers.
31. 6b: logic circuit.
32. 6b: answers.
33. 7: describe a circuit A/B.
34. 7: circuits A and B.
35. 8: complex logic circuit.
36. 8: answers.
37. Design process.
38. 9a: design automatic light.
39. 9a: answers.
40. 9b: design alarm system.
41. 9b: answers.

3.1 The binary numeral system.		
1 h	Classroom	unit3.pps

Activity 1	Individual	unit3.pps (2,3)
• This is a lead-in activity. Students have to read the introduction text and answer the 3 questions. Use slide 2. • The answers are not in the text. They have to remember from unit 1 questions 1 and 2. • They have to guess the last one. You can elicit the word "bit" easily as it has been adopted by all languages in the same form. • Answers are on slide 3.		

The DECIMAL system, or base-10, represents numeric values using 10 symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9.

The BINARY numeral system, or base-2 number system, represents numeric values using two symbols, 0 and 1.

Binary numbers are closely related to digital electronics. **With digital electronics a '1' means that a voltage signal is high and '0' means it is low**. The binary system is used internally by all modern computers.

K1 What electronic component can work as a binary switch? *The transistor.*

When we put together many of them in a single piece of silicon it is called *an integrated circuit (IC).*

In computing and telecommunications a binary digit is called a *bit*. It is the basic unit of information in a binary system.

Activity 2a	Individual	unit3.pps (4,5)
• There is a rule to make number and binary but students should be able to complete the missing numbers in the sequence without formally stating the rule. • Show the series on slide 4. Give them time to try to solve the sequence. Start checking number by number to allow all students to understand the method. • The complete series is on slide 5.		

K2a The binary system is positional, like the decimal one. To count in binary we put in "ones" from the right. Look at the table on the right and try to figure out the rule. Fill in the missing digits.

Binary	Decimal	Binary	Decimal
0	0	1000	8
1	1	1001	9
10	2	1010	10
11	3	1011	11
100	4	1100	12
101	5	1101	13
110	6	1110	14
111	7	1111	15
1000	8	10000	16
1001	9	10001	17

Activity 2b	Individual, pairs	unit3.pps (6,7)

- Present slide 6 to explain the conversion process through the example. It is quite visual.
- Put students to work individually and check each point with their partner.
- Answers are on slide 7 but it would be better to correct the activity number by number with some waiting time in between.
- At the end you can explain that the weight comes from $2x10^{position}$ in binary, the same way that the decimal weight is $10x10^{position}$ in decimal. This would allow them to convert any number.

K2b It is easy to CONVERT any binary number to decimal because each position has a weight. Look at the example and convert binary numbers b), c) and d) to decimal.

	Binary	Binary weight						Decimal
		32	*16*	*8*	*4*	*2*	*1*	
a)	001100	0	0	1	1	0	0	8+4=12
b)	010101	*0*	*1*	*0*	*1*	*0*	*1*	*16+4+1=21*
c)	101010	*1*	*0*	*1*	*0*	*1*	*0*	*32+8+2=42*
d)	100001	*1*	*0*	*0*	*0*	*0*	*1*	*32+1=33*

Check the answers with your partner.

What is the decimal equivalent of one one zero?

Activity 2c	Individual, pairs	unit3.pps (8, 9)

- This time students should to the process in reverse. Again, they should work individually and check answers with their partners.
- If you detect any difficulties tell them that the right way to do it is putting ones in the highest possible position until the addition gives the desired decimal number.
- The empty activity is on slide 8 and the answers are on the 9^{th} slide.

K2c In order to convert from decimal to binary you have to do the inverse process. Convert the following numbers and check your answers with your partner orally.

	Decimal	Binary weight						Binary
		32	*16*	*8*	*4*	*2*	*1*	
a)	41	*1*	*0*	*1*	*0*	*0*	*1*	*101001*
b)	20	*0*	*1*	*0*	*1*	*0*	*0*	*010100*
c)	33	*1*	*0*	*0*	*0*	*0*	*1*	*100001*
d)	63	*1*	*1*	*1*	*1*	*1*	*1*	*111111*

Activity 3a	Individual, pairs	unit3.pps (10, 11, 12)

- Show slide 10 and explain the rules to add binary numbers. Read the example with 3 digits.
- Go through the other three examples. Get some students to read them.
- Move on to slide 11. Students should calculate the two additions individually. When they finish they can read their operations to their partners.
- Check results getting some students to read the operations for all the class. The solutions are on slide 12. Make them aware that electronic machines operate this way because they are based on transistors that work as switches, with only 2 states.

Adding binary numbers is a very simple task. As with decimal numbers, you start by adding the bits (digits) from right to left:

Rules	Examples		
0+0 = 0		*11 1*	*11*
1+0 = 1	1001100	1001001	1000111
0+1 = 1	+ 0010010	+ 0011101	+ 1010110
1+1 = 10	----------	----------	----------
1+1+1 = 11	1011110	1100110	10011101

It is also possible to subtract, multiply and divide. This is how electronic devices operate.

K3a Add the following numbers. Your teacher will ask some of you to read the additions to all the class. Follow the example and practise reading the procedure to prepare.

```
     1
   001  (1)
 + 101  (4+1=5)
 -----
   110  (4+2=6)
```

One plus one equals zero and I carry one.
One plus zero plus zero equals one.
Zero plus one equals one.
The result is one one zero in binary, which is six in decimal.

```
a)  1
   0011  (2+1=3)
 + 1010  (8+2=10)
 ------
   1101  (8+4+1=13)
```

```
b) 111
   1011  (8+2+1=11)
 + 0111  (4+2+1=7)
 ------
  10010  (16+2)=18)
```

3.2 Boolean logic. Logic gates.

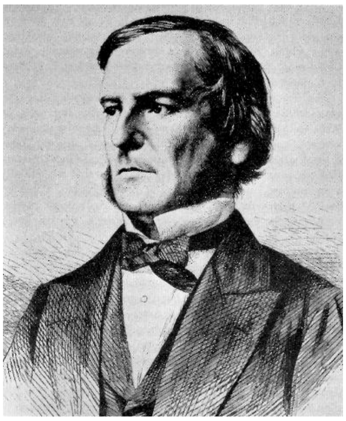
1,5 h	Classroom	unit3.pps

Activity 4a	Individual	unit3.pps (13, 14, 15)

- Introduce Boolean logic with slide 13. Ask students to imagine where to put Boolean logic development on the time line about electronics history that they did in unit 1.
- Ask students to read the text about logical operators and extract information to fill in the table.
- Show answers on slide 15. Tell them that from this moment they will use the electronics expressions to describe logic systems.
- Stress the difference between arithmetic operations and logic operations. Usually electronic circuits do arithmetic and logic operations. It is very important to know when binary digits are numbers or logic states.

In the last lesson you used BINARY DIGITS to represent NUMERIC VALUES.
BINARY DIGITS can also be used to represent LOGIC STATES like “true” (1) or “false” (0).

BOOLEAN LOGIC (or Boolean algebra) is a complete system for logical mathematical operations. It was developed by the English Mathematician and philosopher George Boole in the 1840s. Boolean logic has many applications in electronics, computer hardware and software, and is the basis of all modern digital electronics.



George Boole (1815-1864)

These are examples of Boolean operations:

1 or 0 = 1	1 and 0 =0	not 0 =1	1 and 1= 1	0 or 0 = 0	not 1 = 0

K4a Read the text about Boolean operation representation and fill in the table with the expressions below.

Boolean algebra is based on these logical operations: conjunction x ∧ y (AND), disjunction x ∨ y (OR), and complement or negation ¬x (NOT).

General	*Maths*	*Electronics*
a AND b	a ∧ b	a ·b
a OR b	a ∨ b	a + b
NOT a	¬a	$\overline{a}$

In electronics, the AND is represented as a multiplication, the OR is represented as an addition, and the NOT is represented with an overbar

$a \vee b$	$\overline{a}$	$a \cdot b$	$\neg a$	$a + b$	$a \wedge b$

Activity 4b	Individual	unit3.pps (16, 17, 18, 19, 20, 21, 22)

- Explain to the students that binary and logic maths can be programmed in a computer or implemented with circuits. In the last case we need circuits with wires that carry voltage or not (1 or 0). As with analogue components, symbols are used to represent the physical devices that do the operations (gates).
- Make them aware that symbols and circuits are a global language. For that we need international standards agreed on by international organisations.
- Use slides 17, 19 and 21 to show the main logic gates. Help them to fully understand the functional descriptions before they fill in the truth tables.
- Answers are on slides 18, 20 and 22. You can tell them that there are gates with more input. Ask them to predict how a three-input AND or OR gate works.

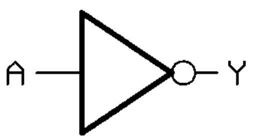
Digital circuits are built from simple on/off switches called **GATES**. These gates have two states: logic high (ON or 1) and logic low (OFF or 0). **TRUTH TABLES** are used to analyse all the possible alternative states of a digital circuit.

You can see the gates symbols on next page. There are two sets of symbols for gates: The traditional ones from America and the new square symbols, a standard by the IEC (International Electrotechnical Commission). You should use the IEC symbols. Anyway the traditional ones are still widely used for simple gates.

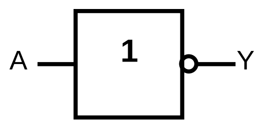
K4b Read the gate descriptions and fill in the truth table for each one.

NOT gate: A NOT gate or inverter has just one input. The output is ON if the input is OFF, and OFF if the input is ON.

$Y=\overline{A}$



NOT symbol

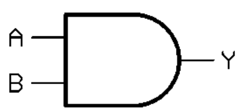


NOT IEC symbol

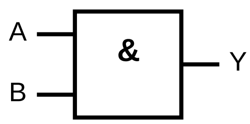
A	Y
0	***1***
1	***0***

AND gate: The output is ON (1) if **both** input signals are ON (1).

$Y=A\cdot B$



AND symbol

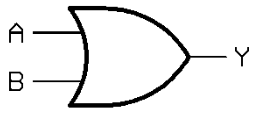


AND IEC symbol

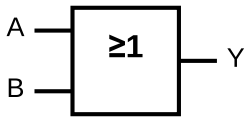
A	B	Y
0	0	***0***
0	1	***0***
1	0	***0***
1	1	***1***

OR gate: The output is ON if **either** or both inputs are ON.

$Y=A+B$



AND symbol

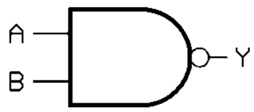


AND IEC symbol

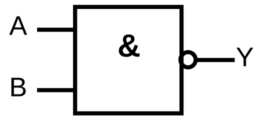
A	B	Y
0	0	***0***
0	1	***1***
1	0	***1***
1	1	***1***

NAND gate: The output is ON **unless both** inputs are ON.

$Y=\overline{A\cdot B}$



NAND symbol

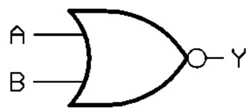


NAND IEC symbol

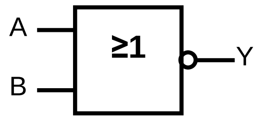
A	B	Y
0	0	***1***
0	1	***1***
1	0	***1***
1	1	***0***

NOR gate: The output is ON if both inputs are OFF.

$Y=\overline{A+B}$



NOR symbol

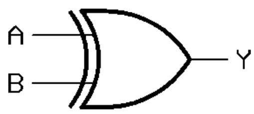


NOR IEC symbol

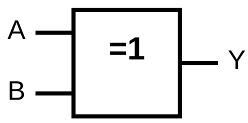
A	B	Y
0	0	***1***
0	1	***0***
1	0	***0***
1	1	***0***

XOR gate: The output is ON if one input is ON and the other is OFF, but will not work if both are ON.

$Y=A\oplus B$



XOR symbol



XOR IEC symbol

A	B	Y
0	0	***0***
0	1	***1***
1	0	***1***
1	1	***0***

Activity 4c	Individual	unit3.pps (23)

- The purpose of this activity is that the students memorize the logic gate symbols. They are going to get more familiar with them in the rest of activities. So, don't assign too much time to this activity.
- They will work in pairs to describe the gate functions and the IEC symbol. Some more able students will be able to memorise both symbols.
- You can show a model dialogue on slide 23. You can let them check in the last activity but at the end they should be able to do it without looking.

4c Let's test if you remember the IEC symbols and the truth tables. In turns, choose one gate and ask your partner for the function description and the IEC symbol gate. Here you have an example:

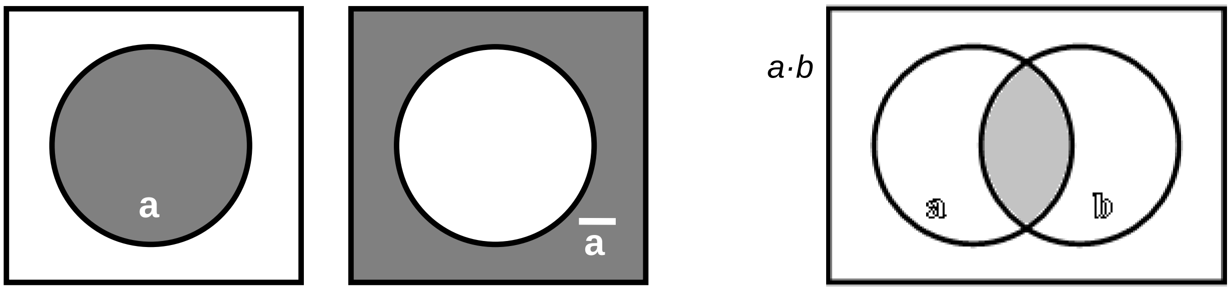
Can you explain how a NAND gate works?
What is the symbol of a NAND Gate?

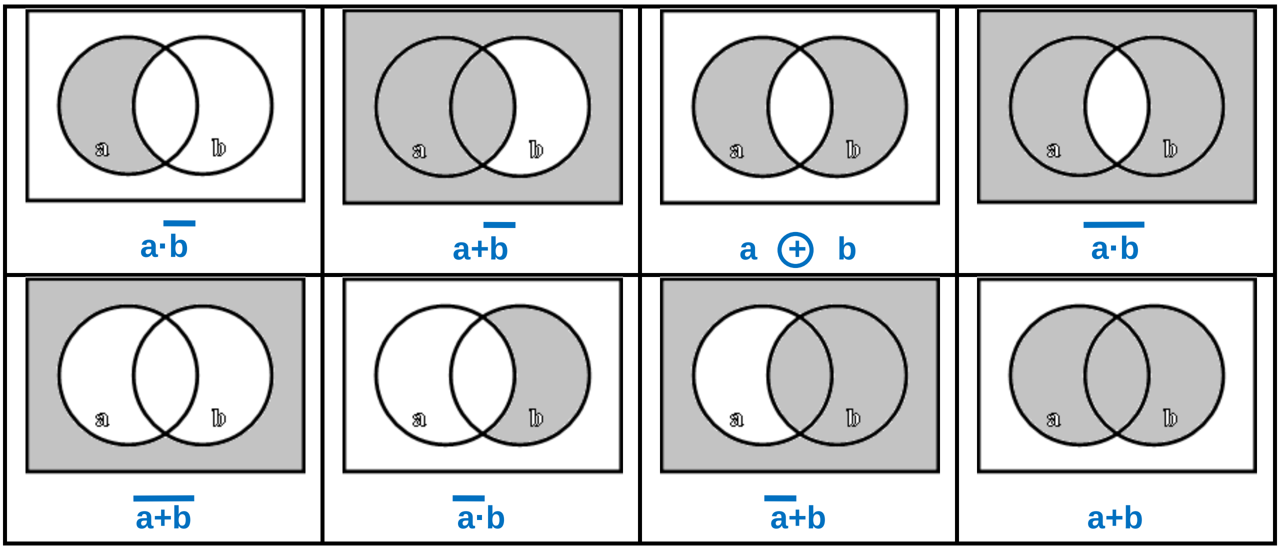
In a NAND gate the output is 0 when both inputs are 1.
It is a square with a "&" symbol inside and with a small circle at the output.

Activity 4d	Individual	unit3.pps (24, 25)

- Logic functions are the basis of Venn diagrams. This more visual representation can help many students but others can find it difficult at first, especially when one of the variables is negated.
- Students have to match logic expressions with Venn diagrams. Start with slide 24 and do one or two matches with the whole class. Let them finish it individually. You can show the completed activity on slide 25.

4d It is possible to represent logic functions with Venn diagrams. Look at the examples. Then identify the 8 diagrams as $\bar{a}\cdot b$, $a\cdot\bar{b}$, $a+b$, $\bar{a}+b$, $a+\bar{b}$, $a\oplus b$, $\overline{a\cdot b}$, $\overline{a+b}$.





Activity 5	Individual	unit3.pps (26, 27, 28)

- You are going to relate logic gates to technologies they already know. Start with the switches on slide 26. Then show slide 27 with the two circuits. Explain that transistors can be combined like the switches and controlled by electric signals. The gates are the inputs and the collector voltage is the output.
- Let students analyse the circuits and fill in the blank with the help of the word bank.
- Check answers on slide 28 and discuss the circuits with the class.

K5 Logic functions can be implemented **electrically with switches** as in these examples.

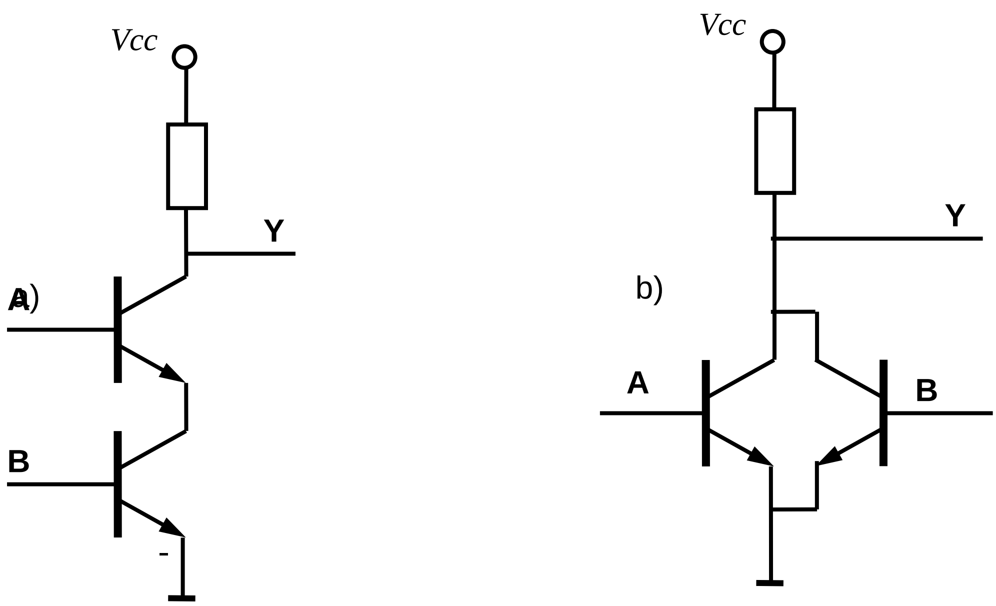
a) AND: The output will only be on when both switches A and B are on.
b) OR: The output will go on if either switch A or B is on.

Real electronic gates are implemented **with transistors**. High voltage means 1 and low voltage means 0. These are simplified circuits of a NAND and a NOR gate. Think how the circuits work and fill in the blanks with these words:

parallel	high	low	NAND	series	NOR

In circuit "a" both transistors are connected in *series*. The output will go low only when both inputs are *high*. So it is a *NAND* gate.

In circuit "b" both transistors are connected in *parallel*. If either input goes up the output goes *low*. So it is a *NOR* gate.



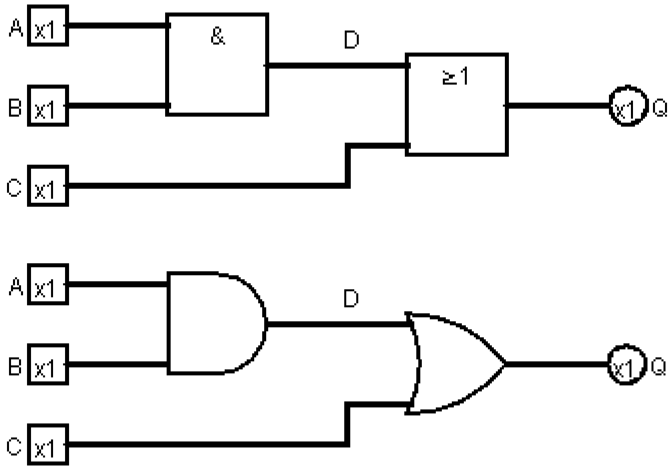
3.3 **Logic circuits.**		
1,5 h	Classroom	unit3.pps

Activity 6a	Individual, class	unit3.pps (29, 30)

- Get the expression first. Explain that in this case it is not necessary to use parentheses because the general precedence rule. AND operator is applied before the OR function as multiplication is applied before addition. A·B+C=(A·B)+C but different from A·(B+C).
- Do this activity with the whole class row by row. Leave some time in between so that students can try by themselves.

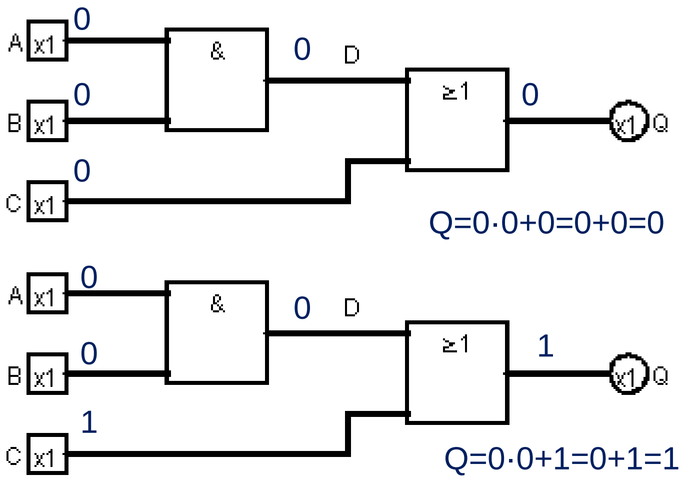
Logic circuits can have many gates, many inputs and more than one output. In this lesson we are going to work with circuits that have a maximum of 3 inputs and 1 output.

K6a The diagram below shows a complex logic gate combining two simple gates. There are three inputs and eight possible outcomes. To complete a truth table go row by row. For each combination of input find first D and then Q.



The two first combinations of the truth table are done as an example. Complete the 6 remaining values.

Expression: Q=A·B+C



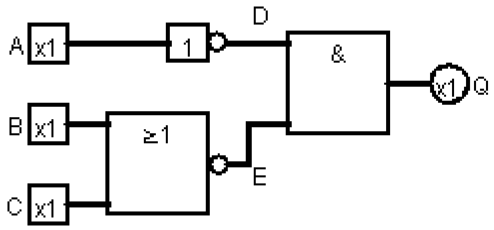
A	B	C	Q
0	0	0	0
0	0	1	1
0	1	0	***0***
0	1	1	***1***
1	0	0	***0***
1	0	1	***1***
1	1	0	***1***
1	1	1	***1***

Activity 6b	Individual, pairs	unit3.pps (31, 32)

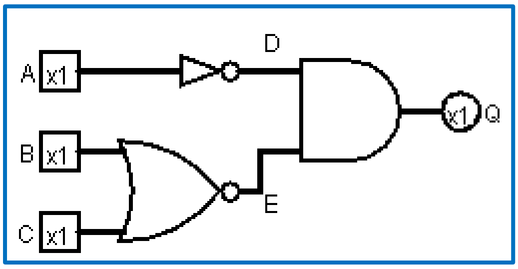
- Ask students to get the diagram and the expression first. Check the right expression before they start with the truth table. They may check answers with their partner.
- Correct the truth table with slide 32 or go row by row writing the logic values on the circuit if students need it.

K6b For the next circuit find the expression, draw the gate diagram with the traditional symbols and complete the truth table.

Expression: $Q = \overline{A} \cdot \overline{(B+C)}$



IEC diagram



Traditional diagram

A	B	C	Q
0	0	0	**1**
0	0	1	**0**
0	1	0	**0**
0	1	1	**0**
1	0	0	**0**
1	0	1	**0**
1	1	0	**0**
1	1	1	**0**

Activity 7	Pairs	unit3.pps (33, 34), worksheets A/B
• Put students into pairs. Show the example of description on slide 33. Give students A and B worksheets A/B. First, students A have to describe the circuit in their worksheet to students B. Students B have to draw it in their workbook. Then the other way round. • Next students A and B have to work individually to get the expressions and the truth table. • When they finish get them to check each other's activity. Then you can show slide 34 with both circuits, expressions and truth tables.		

K7 You have to describe orally a logic circuit from the A/B worksheet to your partner. Your partner will describe one for you. Draw the diagram using IEC symbols.

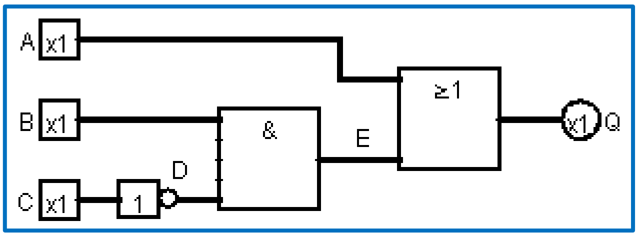
Then you must find the logic expression and fill in the logic table. Finally check results with your partner.

This is an example of descriptions for the circuit in exercise 6b:

> Input A is fed to an inverter. The output from the inverter is called D. Inputs B and C are fed into a NOR gate, whose output is called E. D and E are fed through an AND gate to output Q.

Circuit A to B.

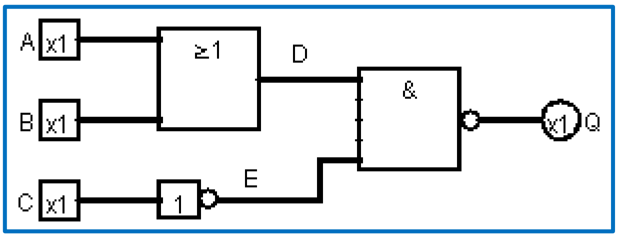
Expression: $Q = A + B \cdot \overline{C}$



A	B	C	Q
0	*0*	*0*	*0*
0	*0*	*1*	*0*
0	*1*	*0*	*1*
0	*1*	*1*	*0*
1	*0*	*0*	*1*
1	*0*	*1*	*1*
1	*1*	*0*	*1*
1	*1*	*1*	*1*

Circuit B to A.

Expression: $Q = \overline{(A+B) \cdot \overline{C}}$

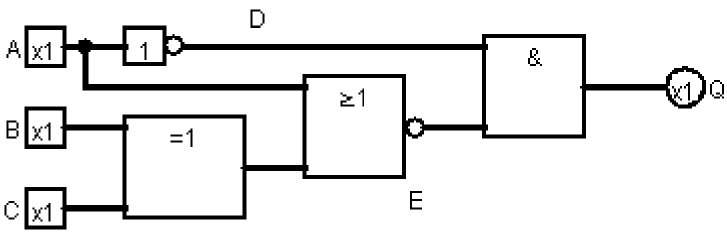


A	B	C	Q
0	*0*	*0*	*1*
0	*0*	*1*	*1*
0	*1*	*0*	*0*
0	*1*	*1*	*1*
1	*0*	*0*	*0*
1	*0*	*1*	*1*
1	*1*	*0*	*0*
1	*1*	*1*	*1*

Activity 8	Individual	unit3.pps (35, 36)

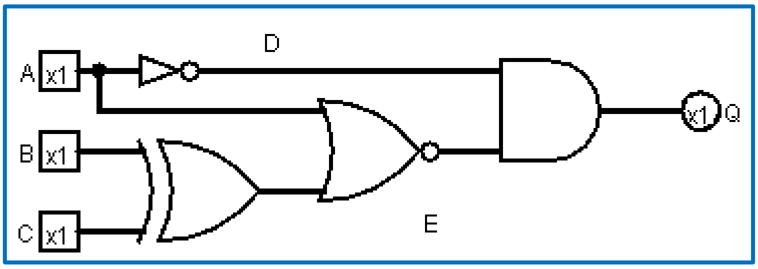
- This circuit is a bit more difficult: it includes 4 gates, input A is used twice and the XOR gate is used for the first time.
- Students have to get the expression and draw the circuit with ANSI symbols first. Check they have got it ok before starting the truth table.

K8 For the next circuit find the expression, draw the gate diagram with the traditional symbols and complete the truth table.



Expression: **$Q = \overline{A} \cdot \overline{(A + (B \oplus C))}$**

Traditional diagram:



A	B	C	Q
0	*0*	*0*	*1*
0	*0*	*1*	*0*
0	*1*	*0*	*0*
0	*1*	*1*	*1*
1	*0*	*0*	*0*
1	*0*	*1*	*0*
1	*1*	*0*	*0*
1	*1*	*1*	*0*

Example for exercise 9:

DESIGN A LOGIC SYSTEM to control heating like this: In automatic mode heating must be on when it is cold and there is somebody inside. In forced mode heating is always on.

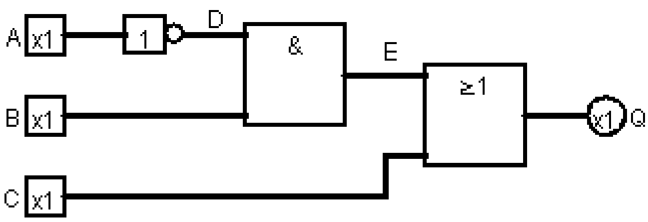
Inputs:
A: temperature (0 cold, 1 warm)
B: presence (0 nobody, 1 somebody)
C: mode (0 automatic, 1 forced)

Output:
Q= heating (0 off, 1 on)

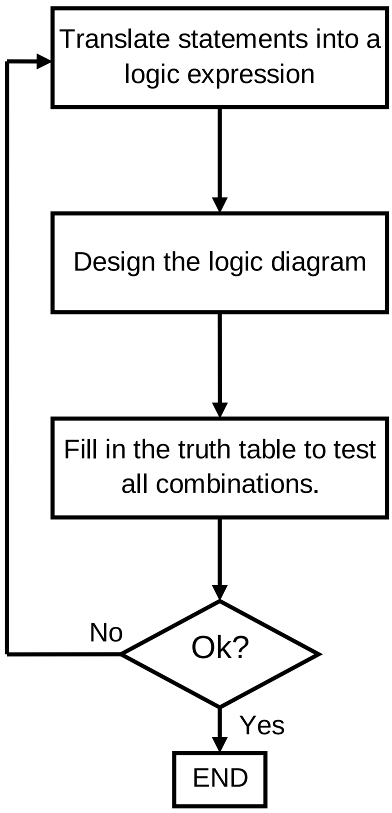
Design process:

Heating= (NOT temperature AND presence) OR mode

$$Q=(\overline{A} \cdot B) + C$$



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



Activity 9a, 9b	Individual, pairs	unit3.pps (37, 38, 39, 40, 41)

- Explain the design process using the example on slide 37. Focus on getting the expression from the problem definition. Afterwards, getting the circuit should be easy.
- In order to check the design, ask students to fill in the truth table to see if the specifications are met. For example, for the first row of the sample design it would be like this: *When the temperature is cold, there is nobody and mode is automatic heating is off.*
- Students should try to do the designs individually. Get a student to do them on the board. Get different students to read aloud line by line to check if it fits the instructions.
- Instructions for design 9a are on slide 38 and the answers on slide 39. Slides 40 and 41 are for design 9b.

K9a Design a logic system to control an automatic light like this: The light must come on when it is dark and somebody passes in front of it.

Inputs:
A: presence (0 nobody, 1 somebody)
B: light_sensor (0 dark, 1 light)

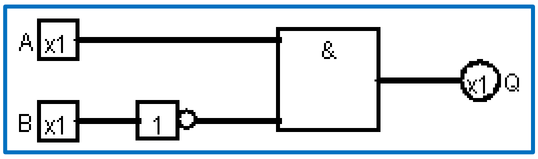
Output:
Q= light (0 off, 1 on)

Expression: light = presence AND (NOT light_sensor)

$Q = A \cdot \overline{B}$

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

Diagram:



K9b Design a logic system to control an alarm bell like this: the alarm bell must ring when the alarm switch is on and either the window or the door are opened.

Inputs:
A: window_open(0 closed, 1 open)
B: door_open (0 closed, 1 open)
C: alarm_on (0 off, 1 on)

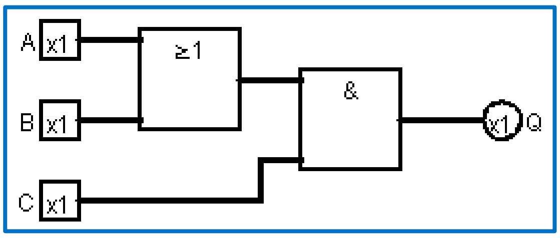
Output:
Q= alarm_bell (0 off, 1 on)

Expression: $Q = (A + B) \cdot C$

alarm_bell = (window_open OR door_open) AND alarm_on

A	B	C	Q
0	0	0	***0***
0	0	1	***0***
0	1	0	***0***
0	1	1	***1***
1	0	0	***0***
1	0	1	***1***
1	1	0	***0***
1	1	1	***1***

Diagram:



Self assessment: Students have to reflect on what they have learnt. Show slide 42 and tell them that they should review the parts of the lesson where they don't answer yes.

QUESTION	No	More or less	Yes
Can I convert between decimal and binary?			
Can I add binary numbers?			
Can I operate using Boole algebra?			
Can I translate logical expressions to gates?			
Can I obtain truth tables from a logic system?			
Can I use simulators to analyse logic systems?			
Can I design logic circuits in order to solve simple technological problems?			

3.4 Simulation work.

3 h	Computer room	logisim software

The instructions to install the logisim free software are on page 7. Students can download it and practise with their own computers from this web page.

http://ozark.hendrix.edu/~burch/logisim/index.html.

Students have to build 6 circuits. The teacher can do some demonstrations at the beginning but the students should be encouraged to discover the programme features by themselves and to use the help menu.

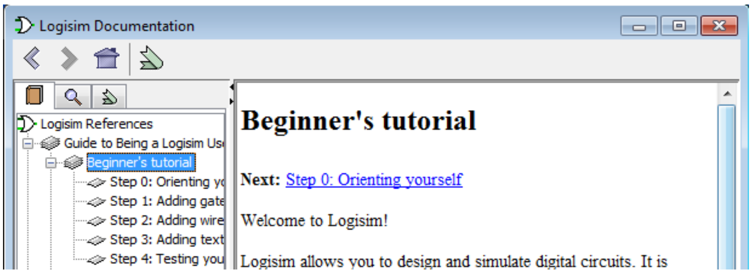
The language for electronics has been taught throughout unit 3. If they lack ICT vocabulary, it can be taught during the demonstration for practice 1.

3.4.1 Logisim basics.

1 h	Computer room	logisim software

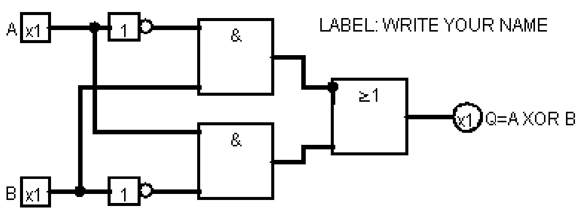
Practice 1: **Follow the tutorial to create a XOR gate with AND, OR and NOT gates.**

Students have to follow the tutorial to build an XOR gate. Go to *help/tutorial* menu to find it.

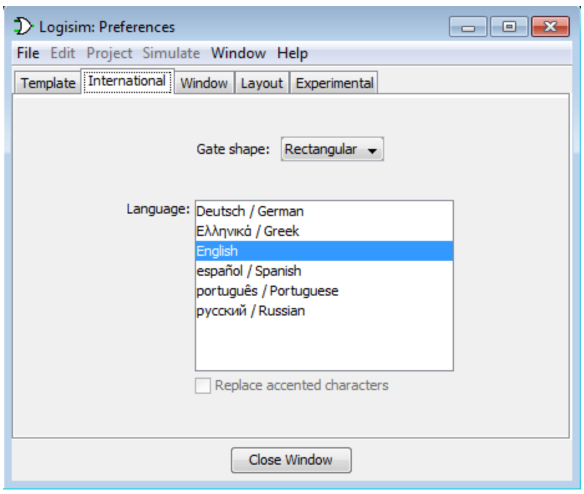


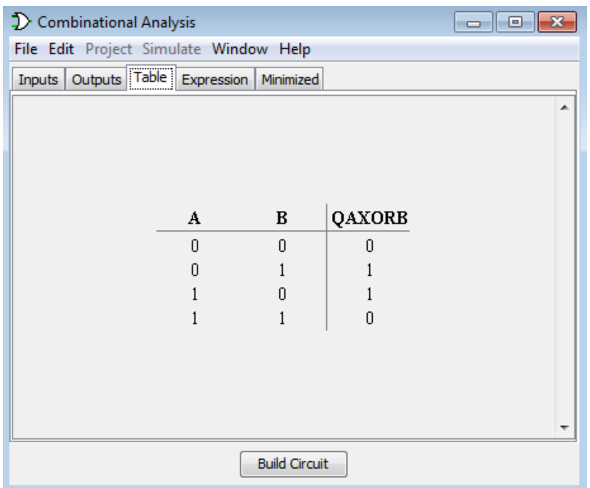
You can either ask students to work by themselves or do a demonstration.

Logisim works with ANSI symbols by default. To change to IEC symbols go to *Window/preferences* and choose rectangular gate shape.



Show students how to get the logic expression and the truth table once the circuit is finished.



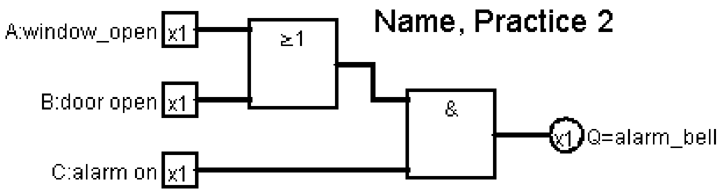


Practice 2: **Build and simulate a circuit.**

Students have to revisit the design they did in activity 9b and build it with logisim on their own.

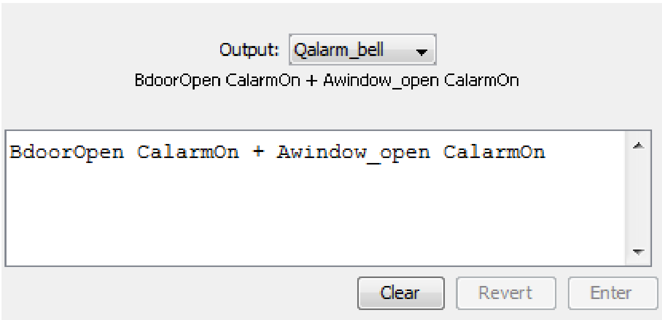
Design a logic system to control an alarm bell like this: the alarm bell must ring when the alarm switch is on and either the window or the door is opened.

Inputs:
A: window_open(0 closed, 1 open)
B: door_open (0 closed, 1 open)
C: alarm_on (0 off, 1 on)
Output:
Q= alarm_bell (0 off, 1 on)



Q= (A + B) · C *alarm_bell = (window_open OR door_open) AND alarm_on*

After drawing the circuit students have to get the logic expression and the logic table from the menu *Project/Analyse circuit*.



Awindow_open	BdoorOpen	CalarmOn	Qalarm_bell
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

3.4.2 Automatic design of logic circuits.		
1 h	Computer room	logisim software

Practice 3: Automatic design from a logic expression.

This is the expression that students have to build into a circuit: $Q = A \cdot \overline{B \cdot C} + B$

Ask them to get the circuit and the truth table automatically. They have to learn how to do it from the programme help, at the *Combinational analysis* section.

You may do a simple demonstration with an easier expression in case they have difficulties understanding the help file.

Place the three inputs and the output and label them. Then go to *Project/Analyse* circuit to introduce the expression in the *Expression* tab: A AND NOT (B AND C) OR B. Then click on *Build circuit*.

In this extract from the help file you can see how to write logic expressions with logisim:

In addition to multiplication and addition standing for AND and OR, an expression you type may contain any of C/Java logical operators, as well as simply the words themselves.

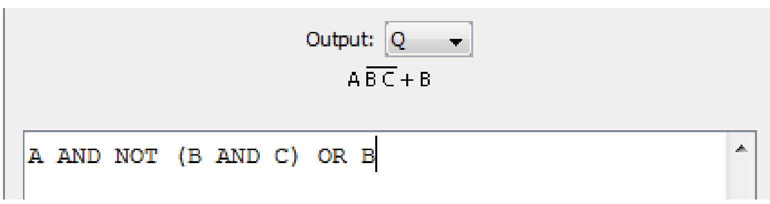
highest precedence	~ ! '	**NOT**
	(none) & &&	**AND**
	^	**XOR**
lowest precedence	+ | ||	**OR**

The following examples are all valid representations of the same expression. You could also mix the operators.

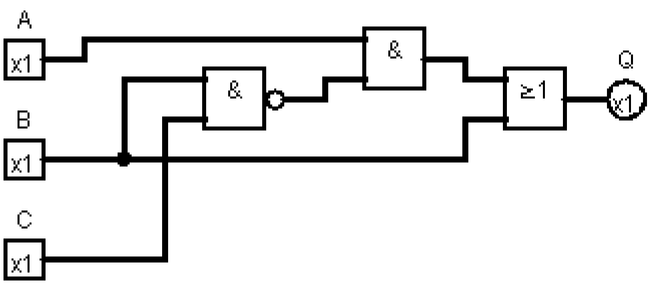
```
a' (b + c)
!a && (b || c)
NOT a AND (b OR c)
```

In general, parentheses within a sequence of ANDs (or ORs or XORs) do not matter. (In particular, when Logisim creates a corresponding circuit, it will ignore such parentheses.)

This is the truth table that they should obtain at the end:



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

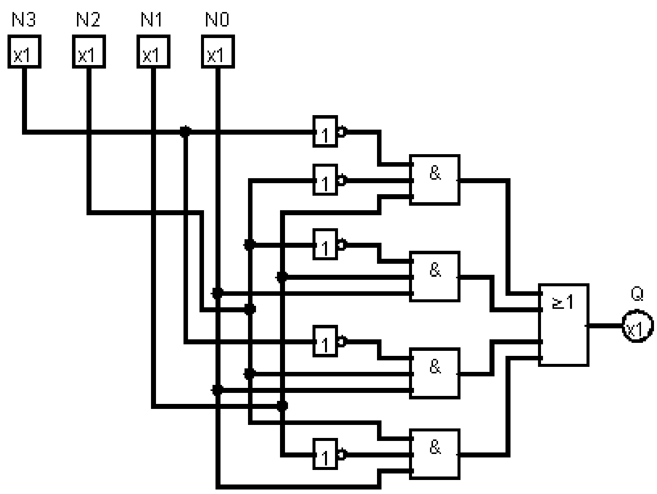


Practice 4: Design a detector of prime numbers.

In this design students will appreciate the power of design and simulation software to deal with complex systems They have to design a logic circuit to detect whether a four-bit number is prime or not. The output will be 1 for prime numbers. The prime numbers from 0 to 15 are: 2, 3, 5, 7, 11 and 13.

This time getting the expression is difficult. The Combinational analysis tool allows us to set the values for the truth table and *Build circuit*. Before that, students have to convert the prime numbers to binary to know which combinations are prime.

N3	N2	N1	N0	Q
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0



3.4.3 Adding and visualising.

1 h	Computer room	logisim software

Practice 5: **Using libraries with integrated circuits.**

Explain that electronic gates are implemented in integrated circuits. The 74XX series of logic gates is built with bipolar transistors. These ICs have 14 pins and contain 4 double input gates. Two pins are used for power supply.

Logisim can work with subcircuits. A library contains many subcircuits. Students can download the library for the 74XX series from the links section at this webpage:

http://ozark.hendrix.edu/~burch/logisim/

This is the name of the library: 7400 series Logisim library from Ben Oztalay

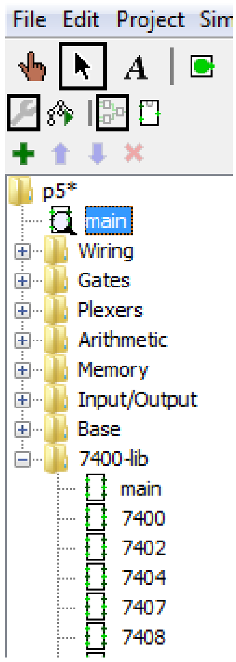
You can show more information on these webpages:

http://en.wikipedia.org/wiki/7400_series

http://en.wikipedia.org/wiki/List_of_7400_series_integrated_circuits

These are the chip numbers for the most common gates:

- 7400: quad 2-input NAND
- 7404: hex inverter
- 7402: quad 2-input NOR gate
- 7408: quad 2-input AND gate
- 7432: quad 2-input OR gate

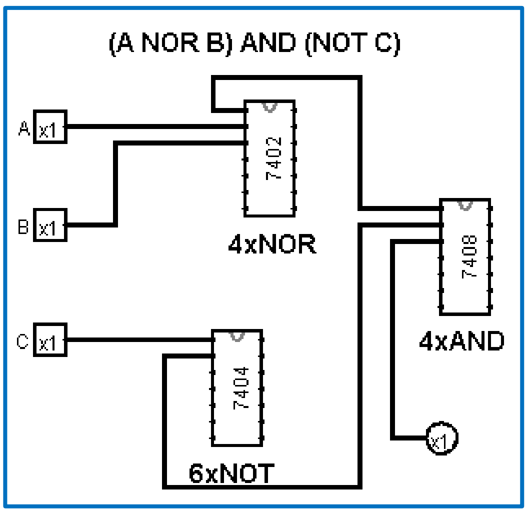


After downloading the library file you have to load it into the program. Go to *Project/load library* and choose the library file. Then you can select the ICs from the component menu on the left and drag them to the canvas area.

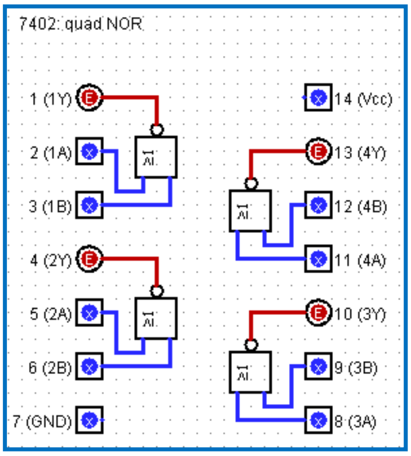
This is the expression that they have to build with the IC subcircuits, instead of using logic symbols directly:

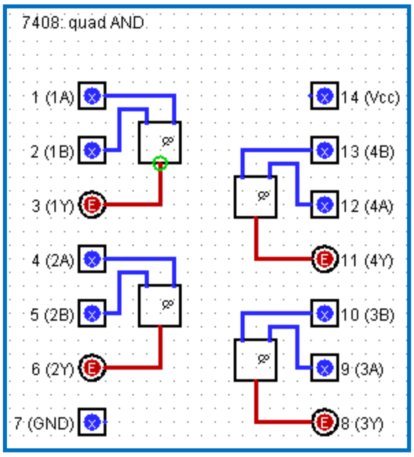
Q = (A NOR B) AND (NOT C)

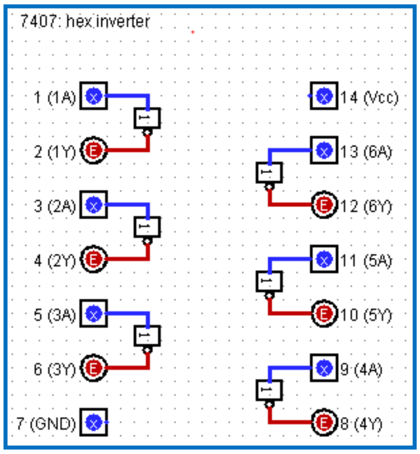
And this is the final circuit:



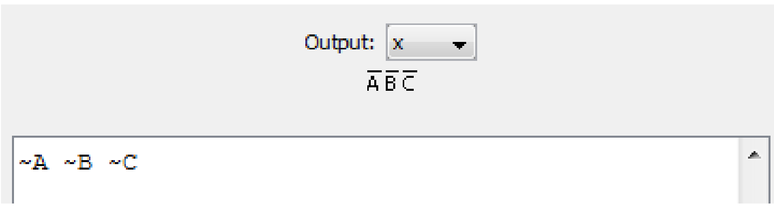
Students can see the layout for the gates by right-clicking on a gate. These are the layouts for the NOR, AND and NOT gates:







Ask them to obtain the expression and the logic table of the circuit.



A	B	C	x
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

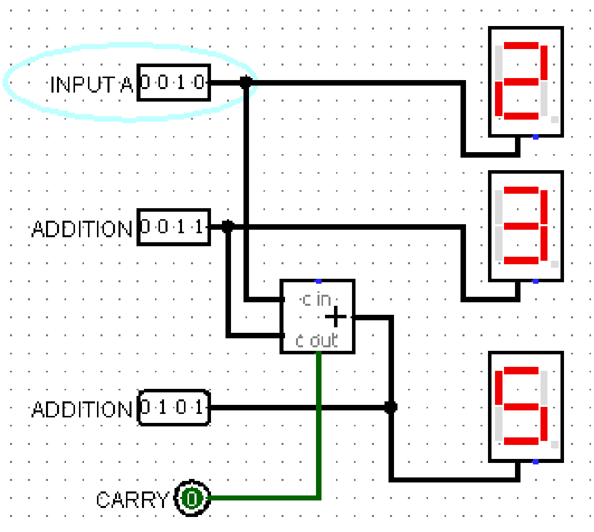
The expression is simpler because the program automatically simplifies it. You can ask the students about this fact.

Practice 6: **Adding binary numbers with logisim.**

Show students the finished circuit and ask them to reproduce it. They will need this:

- Normal inputs and outputs set to 4 bits.
- An *adder* from the *Arithmetic* folder.
- An *hex digit display* from the *Input/output* folder,

This circuit can be used to practise digital-binary conversion, binary addition and to introduce the hexadecimal code.



4 Revision. Assessment.

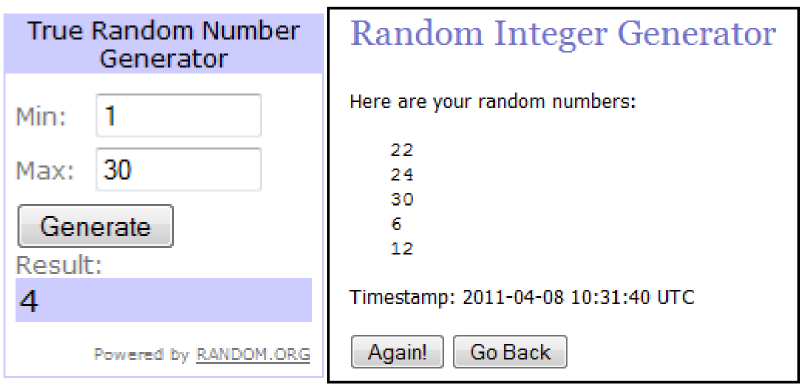
2 h	Classroom	Workbook, summative test

Visual summary	Individual/ group	

- The purpose of this activity is get the students to revisit the coursework and summarise it just using visuals. It consists of two tasks. First the students do their own summary individually. Next they work in groups to bring the summaries together to compare and improve them.
- Personal summary:
  - I suggest setting this task as homework so that every student can take the time they need.
  - Students have to produce a visual summary that fits on a page, preferably in a detached white sheet so that they can work easily with the workbook and the summary. They can't include sentences, just key words. They have to include: a time line, diagrams (tree, Venn...), formulae, symbols, circuits, sample, calculations, truth tables, etc.
  - At this point the individual work can be assessed.
- Group summary:
  - Divide the class into groups of three or four people maximum. In turns, they have to show their summaries to the group and justify what they chose to include. Then they have to agree on a perfect summary. Finally everyone has to complete their summary and write it down again in the space assigned for it in the workbook. This last part can be done as homework.
  - They can use the glossary and useful language notes at the end of the workbook. If necessary you can write some useful language for discussion on the board.
  - This part can be used for language and group work assessment.

Teaching activity	Individual	

- A good part of the content in the three units is new for students and requires high level cognitive demands for abstract thinking, modelling and doing maths calculations. Students need to do individual reflection, practice and repetition work. Some need more than others. Peer teaching or support among students with similar knowledge and cognitive level has proven to be very effective to teach the basics of a new discipline.
- In this activity students have a list of possible exam topics. Randomly they are assigned at least one question. They have to prepare an exam activity similar to the workbook activity and teach it. Due to time limitations only a few of them will do it.
- Procedure:
  - Assign a topic to each student from the table. There are 14 topics. You can assign them in the class list order or in the order they sit in class.
  - This part can be ordered as homework or done in class. They have to prepare individually (with teacher or partner support if necessary) an activity about the topic like the ones in the workbook but with some changes in the input date, or whatever. They have to write down the solution in the workbook too.
  - Obviously, there will not be enough time for all students if you have a big group. Choose. You can choose the ones that are going to present their activities randomly or intentionally select the content you want to review. For the first choice you can use a random number generator like this one:



http://www.random.org/integers/

- Students have to write the activity on the board and ask some other student (chosen by you or them) to do it in front of the class. The peer teacher will do what teachers do: correct and explain the exercise, answer and ask questions to the class. You should only intervene to correct mistakes and control the class.
- This activity can be used for individual assessment of content, language and group work.

Topics for the questions:

1- Questions on the history of electronics.	2- E-waste
3- Electronic block diagrams.	4- Analogue/digital/binary.
4- Ohm's law.	5- Resistor colour code.
5- Types of resistors.	6- Potential dividers.
7- Capacitors, types and units.	8- Charge and discharge of a capacitor.
9- Diodes: function and types.	10- Current calculations for diodes.
11- Transistors: function, parts and types.	12-Transistor as an amplifier: circuit description and calculations.
13- Transistor as a switch: circuit description.	14- Binary-decimal conversion.
15- Binary addition.	16- Basic logic operators: gates and symbols.
17- Logic circuits analysis with 3 inputs and 3 gates.	18- Logic system design with 2 or 3 inputs.

Glossary, useful language	Individual	

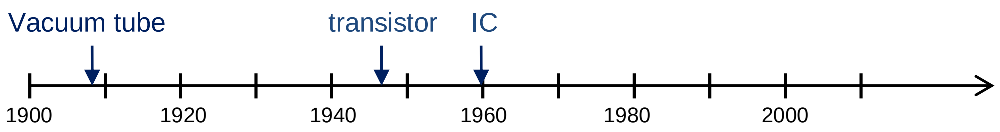
- During the lessons students have to write down new vocabulary they find important and useful English structures or sentences. There is no specific time assigned for this.
- The teacher has to explain the activity the first day and remind them of it a few times throughout the course. At the end it can be used for assessment of individual autonomous work.
- Optionally, at the end of the three units the more important words can be translated to language 1.

Summative assessment	Individual	Worksheets (summative exam)

- This is a sample of a summative exam for the whole block of electronics. The exam has 5 questions, one for unit 1 and two for units 2 and 3. No weight has been set for each.
- The exam covers the essential content that students should now. At least 75% of the tasks can be considered easy compared to course activities. This assessment should be used as part of a more general one that includes communication, interpersonal abilities, course work, etc.
- I suggest reading and explaining the exam to the whole class before students start answering. You may need to elicit or draw some new words such as pump, tap or water deposit.

Key for the summative assessment

01 **a)** Place on the time line three main developments in the history of electronics.



b) Underline the right words:

- A fan is an *electrical/electronic* device because it transforms *information/energy*.
- The *process/input/output* part of a thermometer converts temperature into electric signals.
- A *digital/analogue* signal is less affected by noise.
- *Binary/analogue* signals are more difficult to manipulate and store.

c) What is the problem with e-waste? Propose two measures to deal with it.
E-waste is...

02 a) What are the colours for a 5k6 (10%) resistor?

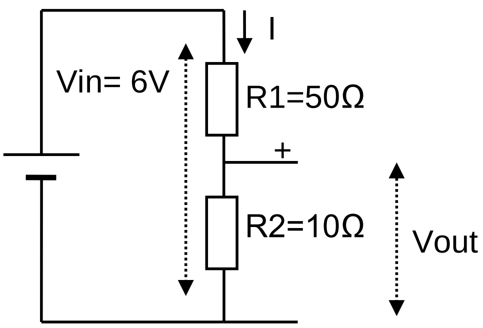
Green/blue/red//silver

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9
Silver	10%
Gold	5%

b) Obtain the minimum and maximum value for a resistor with these colours: brown / green / red // silver

R= 1500 Ω; Rmin=1,350 Ω; Rmax=1,650 Ω

c) What do we call this kind of circuit? *Voltage divider.* Calculate Vout.



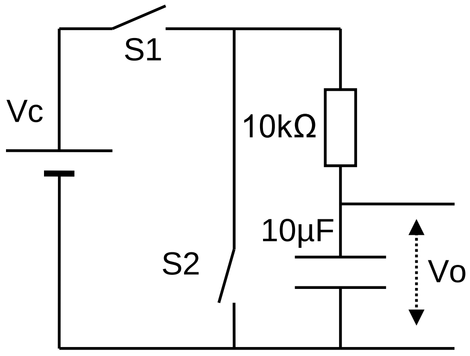
$$Vout = 6 \cdot \frac{10}{50+10} = 6 \cdot \frac{1}{6} = 1\,V$$

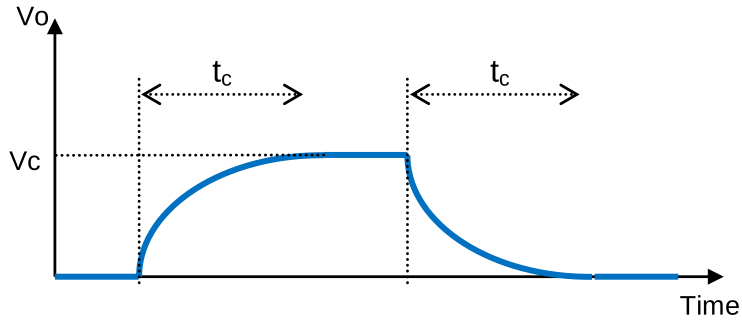
d) Explain how Vo will change depending on the temperature if R2 is a PTC?

If temperature goes up then R2 will go up.

If R2 increases then Vo will go up.

03 a) Calculate the charge and discharge time (t_c) for this circuit:





$T_c = 4 \cdot \tau = 4 \cdot R \cdot C = 4 \cdot 10{,}000 \cdot 0.00001 = 0.4$ seconds

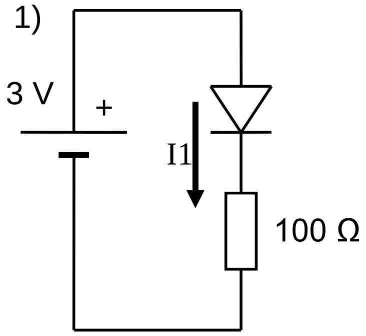
b) Underline the right words:

A *transistor/capacitor/diode* is a semiconductor device that allows current to flow in one direction. The current can only flow from *base/anode* to *cathode/collector*.

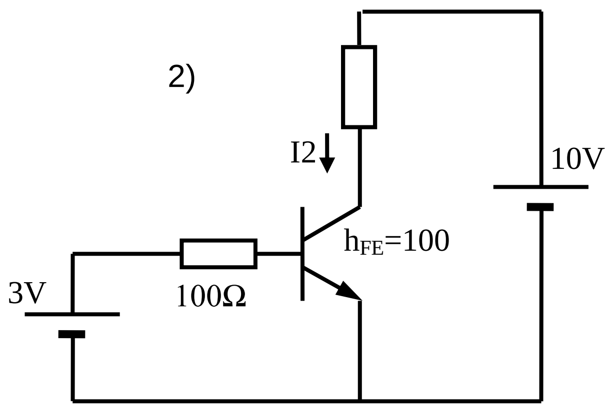
A *transistor/capacitor* is a semiconductor device used to *charge/amplify* electronic signals. It has *two/three* terminals for connection to an external circuit.

c) Calculate the currents in this circuit

1)



2)



$I1 = \frac{3-0.7}{100} = \frac{2.3}{100} = 0.023\ A$ Ib=(3-0.7/100)=I1=0.023 A $I2 = I_c = h_{FE} \cdot I_b = 100 \cdot 0.023 = 2.3A$

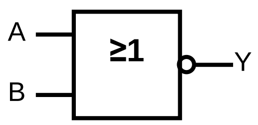
04 a) Convert "a" from binary to digital and "b" from digital to binary.

	Binary	Binary weight					Decimal
		16	*8*	*4*	*2*	*1*	
a)	01110	*0*	*1*	*1*	*1*	*0*	*8+4+2=14*
b)	*10101*	*0*	*0*	*1*	*0*	*1*	5=*4+1*

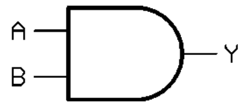
b) Add them in binary.

```
   11
   01110
 + 00101
 ---------
   10011
```

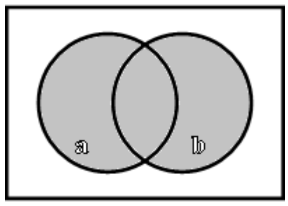
c) Identify the type of gates which these diagrams represent.



NOR



AND

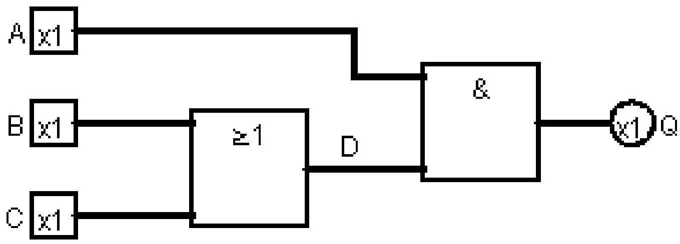


OR

A	B	Y
0	0	**0**
0	1	**1**
1	0	**1**
1	1	**0**

XOR

05 a) Find the expression for this logic system and fill in the truth table.



Expression: **Q= A·(B+C)**

A	B	C	Q
0	0	0	***0***
0	0	1	***0***
0	1	0	***0***
0	1	1	***0***
1	0	0	***0***
1	0	1	***1***
1	1	0	***1***
1	1	1	***1***

b) Design a logic system for a water supply system. The water pump must be on when the deposit is empty or when the tap is open. Find the expression, the circuit with IEC symbols and the truth table. Circle the combination in which the deposit is empty and the tap closed.

Inputs:

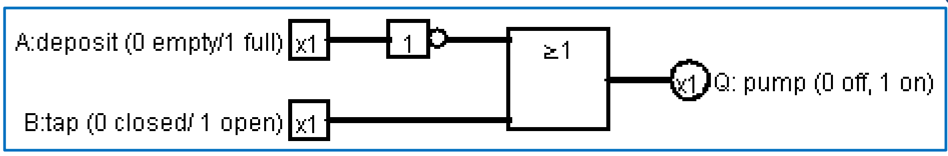
A: deposit (0 empty, 1 full)

B: tap (0 closed, 1 open)

Output:

Q= pump (0 off, 1 on)

Expression: pump= (NOT deposit) OR tap $Q=\bar{A}+B$



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