Department for Education

# Electronics

## GCSE subject content

February 2016

# Contents

# The content for GCSE electronics

## Introduction

1. The GCSE subject content sets out the knowledge, understanding and skills for GCSE specifications in electronics, to ensure progression from key stage 3 national curriculum science and mathematics requirements and the possibility of development into A level. They provide the framework within which awarding organisations create the detail of the subject specifications.

## Subject aims and outcomes

2. Specifications in GCSE electronics will ensure that students have the scientific and mathematical knowledge and understanding and engineering skills to tackle problems in an electronics context. GCSE electronics should be studied in such a way as to develop and maintain their interest in engineering subjects and the appreciation of their relevance to their everyday lives. The scope and nature of such study should be coherent and practical.

GCSE specifications in electronics should enable students to:

- develop scientific knowledge and conceptual understanding of the behaviour of analogue and digital electrical/electronic circuits including a wide range of electronic components
- develop an understanding of the nature, processes and methods of electronics as an engineering discipline to help them answer questions about practical circuits
- be aware of new and emerging technologies
- develop and learn how to apply observational, practical, problem-solving and evaluative skills in the identification of needs in the world around them and to propose and test electronic solutions
- progress to level 3 qualifications in electronics and engineering

## Subject content

3. Specifications for GCSE electronics should require students to develop the electronic engineering, knowledge, understanding and skills set out below.

4. Awarding organisations' specifications should be designed to set out the level of understanding which students are expected to acquire.

5. The knowledge and understanding section also sets out the mathematical skills and knowledge required for electronics. In order to be able to develop their skills, knowledge and understanding in electronics, students need to have been taught and demonstrate competence to select and apply the appropriate areas of mathematics as set out under each topic and the mathematical skills listed in appendix 3.

6. Three appendices provide further details about (1) equations in electronics; (2) units in electronics; and (3) mathematical skills.

## Knowledge and understanding

7. GCSE specifications in electronics should reflect the aims and learning outcomes outlined above, and should include the knowledge, understanding and skills listed below, giving due consideration to the assessment objectives. The essential subject content outlined here provides the framework for developing a coherent study at GCSE.

8. This content sets out the full range of content for GCSE specifications in electronics. Awarding organisations may, however, use any flexibility to increase depth, breadth or context within the specified topics, as long as the rigour and challenge of the specification is maintained.

9. GCSE specifications in electronics should require students to demonstrate and apply knowledge and understanding of:

### Scientific communication

- how to use scientific vocabulary, symbols, terminology and definitions
- how to use SI units

### Use of apparatus

- how to connect electrical circuits
- how to take measurements on electrical circuits using multimeters (on voltage, current and resistance ranges), timing equipment, logic probes and oscilloscopes (or computers configured as oscilloscopes)

### Basic circuits

- Electronic systems and sub-systems
    - the way in which electronic systems are assembled from sensing, processing and output sub-systems

  - the principles of a range of sensing, processing and output sub-systems
  - the need for and use of transducer drivers

- Circuit concepts

  - the communication of electrical circuits using standard circuit symbols connected in standard ways
  - how to analyse circuits in terms of voltage, current, resistance, energy and power
  - how to take measurements to test electrical components and circuits, including investigating current-voltage characteristics

- Resistive components in circuits

  - the qualitative and quantitative effects of resistors and resistor combinations (series and parallel) in circuits
  - the design and testing of sensing circuits using resistors and a range of passive sensors, including light, temperature, pressure, moisture, switch, sound and pulse generator
  - the selection of resistors for circuits, considering resistance, tolerance and power dissipation

- Switching circuits

  - how to analyse and compare the action of switching circuits based upon npn transistors, MOSFETs and voltage comparator ICs
  - how to perform calculations on switching circuits based upon npn transistors
  - the use of data to design switching circuits using npn transistors and comparators

- Applications of diodes

  - the current-voltage behaviour and uses of silicon diodes for component protection in DC circuits and half-wave rectification AC circuits
  - how zener diodes are used in voltage regulation circuits

- Uses of mathematics

  - the application of the equations relating pd, current, resistance, power, energy and time and solve problems for circuits which include resistors in series, resistors in parallel and resistors in sensing and transistor circuits

$$R=\frac{V}{I};\ P=VI=I^2R=\frac{V^2}{R};\ E=Pt;$$

$$R=R_1+R_2;\ R=\frac{R_1R_2}{R_1+R_2};\ I_C=h_{FE}I_B;\ V_{OUT}=\frac{R_2}{R_1+R_2}V_{IN}$$

- calculate expected voltage values in order to test circuits
- plotting and interpreting I-V characteristic graphs and switching graphs

## Digital circuits

- Combinational logic systems

  - the meaning of a logic level
  - the identification and behaviour of logic gates: NOT and 2-input AND, OR, NAND and NOR, singly and in combination
  - how to use truth tables and basic Boolean manipulation for systems of gates
  - how to design processing systems consisting of logic gates to solve problems, incorporating pull-up and pull-down resistors to provide the correct logic level

- Timing circuits

  - how the voltage across a charging or discharging capacitor in an RC circuit varies with time and the effect on the voltage-time graph of varying the values of R and/or C
  - how an RC network can be used to produce a time delay
  - the characterisation of monostable time-delay and astable circuits
  - how to configure a 555-timer as a monostable or an astable and to perform relevant calculations
  - how to use an oscilloscope (or a computer configured as an oscilloscope) to determine the properties of time delay and astable circuits

- Sequential systems

  - how to describe the action of rising-edge-triggered D-type flip-flops and latches (registers), BCD and decade counters
  - how to use timing diagrams for flip-flops, BCD counters and decade counters
  - how to construct 1- and 2-bit binary up-counters from D-type flip-flops
  - how to design and analyse systems using counters and combinational logic to produce a given sequence

- Uses of mathematics
  - logic simplification using $\overline{A+B} = \overline{A}.\overline{B}$; $\overline{A.B} = \overline{A}+\overline{B}$
  - the interpretation of decay graphs for $RC$ networks, $V$-$t$ graphs for monostables and astables and timing graphs for counters
  - the calculation of the time delay of a monostable and frequency, period, mark-space ratio for an astable

$$T = 1.1RC;\ f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2)C};\ \frac{T_{ON}}{T_{OFF}} = \frac{R_1 + R_2}{R_2}$$

## Interfacing digital to analogue circuits

- Interface circuits
  - the action of a Schmitt inverter and how it can be used in debouncing mechanical switches and analogue sensors
  - the comparison of the properties of transistors, comparators and Schmitt inverters as interfaces between analogue and digital systems
  - how to design transistor switching circuits to interface input sensors to outputs

## Analogue communications

- Operational amplifiers (op-amps)
  - how to define and calculate the voltage gain and bandwidth of an amplifier and the trade-off between them
  - how to draw circuits for non-inverting and inverting op-amp amplifier circuits and use of the gain formulae in calculations
  - how the output signal of an amplifier may be affected by clipping distortion
  - how to draw circuits for mixers based on a summing op-amp circuit and calculate the output voltage

- Uses of mathematics
  - calculations involving the gain of amplifiers:

$$G = \frac{V_{OUT}}{V_{IN}};\ G = 1 + \frac{R_F}{R_1};\ G = -\frac{R_F}{R_{IN}};\ V_{OUT} = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + ....\right)$$

  - how to use voltage gain-$f$ graphs to determine bandwidth; $V$-$t$ graphs to illustrate clipping distortion; calculations from $V_{IN}$-$V_{OUT}$ graphs

## Control circuits

- Microcontrollers

- the nature of a microcontroller as a programmable integrated circuit into which software can be loaded to carry out a range of different tasks
- how microcontrollers can be interfaced with sensing circuits and output devices
- how to design flowchart programs to enable microcontrollers to perform tasks

## Electronics skills

10. Specifications for GCSE electronics should require students, in the context of the knowledge and understanding specified, to demonstrate the ability to:

- analyse a problem[1] to enable solutions to be developed
- develop a design brief to solve a problem
- propose an electronic system, composed of sub-systems, to satisfy a design brief
- make predictions about the way that electronic systems behave
- design and build an electronic system, modelling its performance against the design brief, modifying as appropriate
- plan tests to take measurements, to explore a problem, selecting appropriate techniques and instruments
- evaluate practical risks in system development and application
- carry out tests having due regard to the correct manipulation of apparatus, accuracy of measurement and Health and Safety considerations
- take and record measurements on electrical circuits
- report results using standard scientific conventions
- evaluate the performance of the electronic system against the design brief
- suggest improvements to the electronic system following evaluation

### Assessment of electronics skills

11. Specifications for GCSE electronics should assess all these electronics skills by requiring students to undertake a single extended System Design and Construction task.

---

[1] In the context of GCSE electronics skills, 'problem' is interpreted broadly, to embrace:

- problem – difficulties in a situation e.g. people with partial hearing cannot hear the doorbell
- context – looking at situations for possible design openings e.g. people crossing the road
- opportunity – possibilities arising e.g. from a new improved component

# Appendix 1

## Equations in electronics

(a) In solving quantitative problems, students should be able correctly to use the following relationships using standard SI units, without them being provided:

| | |
|---|---|
| potential difference = current × resistance | $V = IR$ |
| power = potential difference × current | $P = VI$ |
| power = (current)$^2$ × resistance | $P = I^2R$ |
| energy transfer = power × time | $E = Pt$ |

| | |
|---|---|
| $R = R_1 + R_2$ | resistors in series |
| $R = \dfrac{R_1 R_2}{R_1 + R_2}$ | resistors in parallel |

(b) In addition, students should be able correctly to select from a list and apply the following relationships

| | |
|---|---|
| $V_{\text{OUT}} = \dfrac{R_2}{R_1 + R_2} V_{\text{IN}}$ | potential divider |
| $P = \dfrac{V^2}{R}$ | power dissipated in a resistor |
| $I_{\text{C}} = h_{\text{FE}} I_{\text{B}}$ | current gain of a junction transistor |
| $f = \dfrac{1}{T}$ | frequency, period relationship |
| $T = 1.1RC$ | time delay of a monostable |
| $f = \dfrac{1.44}{(R_1 + 2R_2)C}$ | frequency of an astable |
| $\dfrac{T_{\text{ON}}}{T_{\text{OFF}}} = \dfrac{R_1 + R_2}{R_2}$ | mark/space ratio of an astable |
| $G = \dfrac{V_{\text{OUT}}}{V_{\text{IN}}}$ | amplifier voltage gain |
| $G = 1 + \dfrac{R_{\text{F}}}{R_1}$ | non-inverting op-amp circuit voltage gain |
| $G = -\dfrac{R_{\text{F}}}{R_{\text{IN}}}$ | inverting op-amp circuit voltage gain |
| $V_{\text{OUT}} = -R_{\text{F}}\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \ldots\right)$ | summing amplifier output voltage |
| $\overline{A + B} = \overline{A}.\overline{B}$ and $\overline{A.B} = \overline{A} + \overline{B}$ | Boolean identities |

# Appendix 2

## SI units

Students should recognise, carry out calculations and be able to communicate using:

(a) The following SI units:

ampere (A), second (s), hertz (Hz), joule (J), watt (W), volt (V), ohm (Ω);

(b) The following SI multipliers:

p, n, μ, m, k, M, G, T.

# Appendix 3

## Mathematical skills required for GCSE electronics

### 1. Arithmetic and numerical computation

(a) Recognise and use expressions in decimal form
(b) Recognise and use expressions in standard form
(c) Use ratios, fractions and percentages
(d) Calculate squares and square roots

### 2. Handling data

(a) Use an appropriate number of significant figures
(b) Find arithmetic means
(c) Make order of magnitude calculations

### 3. Algebra

(a) Understand and use the symbols =, <, <<, >>, >, ∝, ~
(b) Change the subject of an equation
(c) Substitute numerical values into algebraic equations using appropriate units for physical quantities
(d) Solve simple algebraic equations
(e) Use simple Boolean identities

### 4. Graphs

(a) Translate information between graphical and numeric form
(b) Plot two variables from experimental or other data
(c) Draw an appropriate trend line onto plotted data
(d) Interpret data presented in graphical form
(e) Determine the slope of a graph
(f) Calculate the rate of change from a graph showing a linear relationship
(g) Draw and use the slope of a tangent to a curve as a measure of rate of change

Department for Education



About this publication:
enquiries www.education.gov.uk/contactus
download www.gov.uk/government/publications

Reference: DFE-00039-2016