3.13 Electronics (A-level only)

This option is designed for those who wish to learn more about modern electronic technologies as a development of their core work in electricity. A variety of discrete devices is introduced followed by discussions of both analogue and digital techniques ranging from the operational amplifier to digital signal processing. The option ends with a look at the issues surrounding data communication.

3.13.1 Discrete semiconductor devices (A-level only)

3.13.1.1 MOSFET (metal-oxide semiconducting field-effect transistor) (A-level only)

Content
Simplified structure, behaviour and characteristics.
Drain, source and gate.
V_{DS}, V_{GS}, I_{DSS}, and V_{th}
Use as a switch, use as a device with a very high input resistance.
Use in N-channel, enhancement mode only is required.

3.13.1.2 Zener diode (A-level only)

Content
Characteristic curve showing zener breakdown voltage and typical minimum operating current.
Anode and cathode.
Use with a resistor as a constant voltage source.
Use to provide a reference voltage.
Use as a stabiliser is not required.

3.13.1.3 Photodiode (A-level only)

Content
Characteristic curves and spectral response curves.
Use in photo-conductive mode as a detector in optical systems.
Use with scintillator to detect atomic particles.

3.13.1.4 Hall effect sensor (A-level only)

Content
Use as magnetic field sensor to monitor attitude.
Use in tachometer.
Principles of operation are not required.

3.13.2 Analogue and digital signals (A-level only)

3.13.2.1 Difference between analogue and digital signals (A-level only)

Content

Bits, bytes.

Analogue-to-digital conversion:

- sampling audio signals for transmission in digital form
- conversion of analogue signals into digital data using two voltage levels
- quantisation
- sampling rate
- effect of sampling rate and number of bits per sample on quality of conversion
- advantages and disadvantages of digital sampling
- process of recovery of original data from noisy signal
- effect of noise in communication systems.

Pulse code modulation.

Students should appreciate the use of a variety of sensors to collect analogue data.

The ability to carry out binary arithmetic is not required. Knowledge of binary numbers 1 to 10 is adequate.

3.13.3 Analogue signal processing (A-level only)

3.13.3.1 LC resonance filters (A-level only)

Content

Resonant frequency, $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Only parallel resonance arrangements are required.

Analogy between LC circuit and mass–spring system.

Inductance as mass analogy.

Capacitance as spring analogy.

Derivation of the equation is not required.

Energy (voltage) response curve.

The response curve for current is not required.

Q factor, $Q = \frac{f_0}{f_B}$

f_B is the bandwidth of the filter at the 50% energy points.

3.13.3.2 The ideal operational amplifier (A-level only)

Content

Operation and characteristics of an ideal operational amplifier:

- power supply and signal connections
- infinite open-loop gain
- infinite input resistance.

Open-loop transfer function for a real operational amplifier, $V_{out} = A_{OL}(V_+ - V_-)$

Use as a comparator.

The operational amplifier should be treated as an important system building block.

3.13.4 Operational amplifier in:

3.13.4.1 Inverting amplifier configuration (A-level only)

Content

Derivation of $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$, calculations.

Meaning of virtual earth, virtual-earth analysis.

3.13.4.2 Non-inverting amplifier configuration (A-level only)

Content

$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$

Derivation is not required.

3.13.4.3 Summing amplifier configuration (A-level only)

Content

$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \ldots\right)$

Difference amplifier configuration.

Derivation is not required.

$V_{out} = \left(V_+ - V_-\right)\frac{R_f}{R_1}$

Derivation is not required.

3.13.4.4 Real operational amplifiers (A-level only)

Content

Limitations of real operational amplifiers.

Frequency response curve.

$gain \times bandwidth = constant$ for a given device.

3.13.5 Digital signal processing (A-level only)

3.13.5.1 Combinational logic (A-level only)

Content

Use of Boolean algebra related to truth tables and logic gates.

$\overline{A}$ = **not** A

$A \cdot B$ = A **and** B

$A + B$ = A **or** B

Identification and use of AND, NAND, OR, NOR, NOT and EOR gates in combination in logic circuits.

Construction and deduction of a logic circuit from a truth table.

The gates should be treated as building blocks. The internal structure or circuit of the gates is not required.

3.13.5.2 Sequential logic (A-level only)

Content

Counting circuits:

- Binary counter
- BCD counter
- Johnson counter.

Inputs to the circuits, clock, reset, up/down.

Outputs from the circuits.

Modulo-n counter from basic counter with the logic driving a reset pin.

The gates should be treated as building blocks. The internal structure or circuit of the gates is not required.

3.13.5.3 Astables (A-level only)

Content

The astable as an oscillator to provide a clock pulse.

Clock (pulse) rate (frequency), pulse width, period, duty cycle, mark-to-space ratio.

Variation of running frequency using an external RC network.

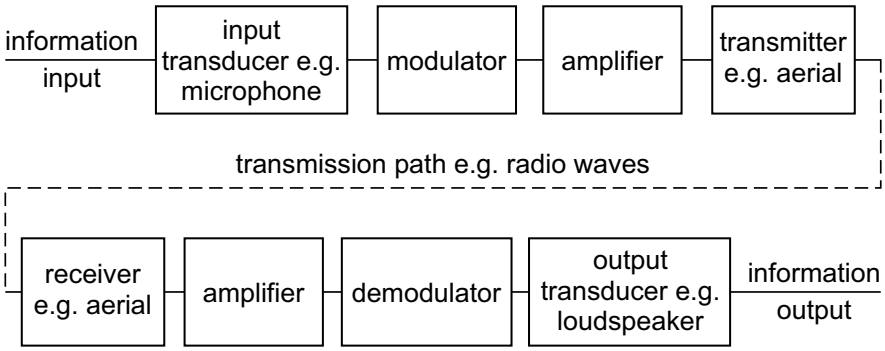
Knowledge of a particular circuit or a specific device (eg 555 chip) will not be required.

3.13.6 Data communication systems (A-level only)

3.13.6.1 Principles of communication systems (A-level only)

Content

Communication systems, block diagram of 'real time' communication system.



Only the purpose of each stage is required.

3.13.6.2 Transmission media (A-level only)

Content

Transmission-path media: metal wire, optic fibre, electromagnetic (radio, microwave).

Ground wave, refraction and reflection of sky waves, diffraction of long-wavelength radiation around the Earth's surface.

Satellite systems and typical transmission frequencies.

Students should recognise that up-links and down-links require different frequencies so that the receivers are not de-sensed.

Advantages and disadvantages of various transmission media. Students should consider data transmission rate, cost, and security issues.

3.13.6.3 Time-division multiplexing (A-level only)

Content

Basic principles of time-division multiplexing.

3.13.6.4 Amplitude (AM) and frequency modulation (FM) techniques (A-level only)

Content

Principles of modulation; bandwidth.

Carrier wave and information signal.

Details of modulation circuits for modulating a carrier signal with the information signal will not be required.

Graphical representation of both AM and FM modulated signals.

A detailed mathematical treatment is not required.

Students will be expected to identify the carrier frequency and the information frequency from a graph of the variation of signal voltage with time.

Bandwidth requirements of simple AM and FM:

$bandwidth = 2f_{\mathrm{M}}$ for AM

$bandwidth = 2(\Delta f + f_{\mathrm{M}})$ for FM

Data capacity of a channel.

Comparison of bandwidth availability for various media.