GCE A LEVEL

eduqas
Part of WJEC

WJEC Eduqas GCE A LEVEL in

ELECTRONICS

ACCREDITED BY OFQUAL
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GUIDANCE FOR TEACHING

Teaching from 2017
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wjec cbac

SUMMARY OF AMENDMENTS

Version	Description	Page number
2	Changes required due to submission of NEA switching to electronic upload: Section 'Component 3 – NEA' replaced and marked exemplar removed as exemplars are now available on Portal.	30-32

Contents

Introduction

WJEC Eduqas A level Electronics provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, electronics and to recognise its importance in their own lives and in today's technological society.

The WJEC Eduqas A level in Electronics will ensure that learners have the electronic and mathematical knowledge and electronic engineering skills to solve problems. This should enable learners to appreciate how many problems in society can be tackled by the application of the scientific ideas in the field of electronics using engineering processes. The scope and nature of the learner's study should be coherent and practical. The practical work enables learners to see the theoretical knowledge contained in the specification in action and to gain greater understanding of the knowledge in a practical context.

Studying WJEC Eduqas A level Electronics enables learners to:

- develop essential scientific knowledge and conceptual understanding of the behaviour of electrical/electronic circuits
- develop and demonstrate a deep understanding of the nature, processes and methods of electronics as an engineering discipline
- develop competence and confidence in a variety of practical, mathematical and problem solving skills
- develop and learn how to apply observational, practical and problem-solving skills in the identification of needs in the world around them and the testing of proposed electronic solutions
- develop and learn how to apply creative and evaluative skills in the development and assessment of electronic systems to solve problems
- develop their interest in electronics, including developing an interest in further study and careers associated with electronics.

Learners should be prepared to apply the knowledge, understanding and skills specified in a range of theoretical, practical, industrial and environmental contexts. Learners' understanding of the connections between the different elements of the subject and their holistic understanding of the subject is a requirement of this specification. In practice, this means that learners will be required to draw together different areas of knowledge, skills and understanding from across the full course of study.

Practical work is an intrinsic part of this specification. It is vitally important in developing a conceptual understanding of many topics and it enhances the experience and enjoyment of electronics. The practical skills developed are also fundamentally important to learners going on to further study in electronics, engineering and related subjects, and are transferable to many careers.

Additional ways that WJEC can offer support

- Specimen assessment materials and mark schemes
- face-to-face CPD events
- examiners' reports on each question paper
- free access to past question papers and mark schemes via the secure website
- free access to question bank
- direct access to the subject officer
- free eBook resources
- free online resources
- exam results analysis
- online examination review.

Aims of the Guidance for Teaching

The principal aim of the Guidance for Teaching is to support teachers in the delivery of the new **WJEC Eduqas A Level Electronics** specification and to offer guidance on the requirements of the qualification and the assessment process.

The guide is **not intended as a comprehensive reference**, but as support for professional teachers to develop stimulating and exciting courses tailored to the needs and skills of their own learners in their particular institutions. In addition, it must not be used instead of the specification, but must be used to support the delivery of it.

Possible Delivery Models

Model A

This model will allow for AS and A level learners to be taught in the same class. Whilst the AS students are completing the AS NEA tasks, the same tasks can be utilised as a teaching tool consolidating knowledge and skills for the A level students. AS Component 1 contains aspects of both A level Component 1 and Component 2. Centres with only A level learners could also follow this model. The core concepts (first four sections at AS) can be taught when required in the other sections.

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Model B

Where only A level learners are to be taught in the class.

Year								
12	Component 1							
	Semiconductor components	Logic systems	Operational amplifiers	Signal conversion	AC circuits and passive filters	Communications systems	Wireless transmission	Instrumentation systems
	Core concepts System synthesis DC Electrical circuits Input and output sub-systems Energy and power							
	Practical work							
13	Component 2							
	Timing circuits	Sequential logic systems	Microcontrollers	Digital communications	Optical communication	Mains power supply systems	High power switching systems	Audio systems
	Core concepts System synthesis DC Electrical circuits Input and output sub-systems Energy and power							
	Practical work and Component 3 (NEA)							

Whilst the AS NEA tasks are not required for the A level it would be a good preparation for developing the skills required to complete the A level NEA tasks.

Assessment Objectives

	Objective
AO1	Demonstrate knowledge and understanding of the: (1a) ideas of electronics (1b) techniques and procedures of electronics.
AO2	Apply knowledge and understanding of the: (1a) ideas of electronics (1b) techniques and procedures of electronics.
AO3	Analyse problems and design: (1a) design electronic systems to address identified needs (1b) build electronic systems to address identified needs (only assessed in NEA) (1c) test electronic systems to address identified needs (only assessed in NEA) (1d) evaluate electronic systems to address identified needs.

The following questions in the sample assessment materials exemplify the WJEC interpretation of each of the assessment objectives:

AO1: demonstrate knowledge and understanding of ideas, techniques and procedures of electronics.

Component 1 Q3(a) asks learners to give two characteristics of an ideal op-amp This question is based upon statement 1.3a (recall the characteristics of an ideal op-amp…) of the specification. Since the question requires learners to demonstrate their knowledge of an electronic idea in a familiar context, it is classed as AO1 element 1a. The question is also classed as 'knowledge in isolation' since this will be recall of information directly linked to the specification statement.

Component 1 Q4(a) requires the learner to explain the features on the I-V characteristic curve for a p-n junction. This question is based upon statement 1.1a (recall the conduction processes in n- and p-type semiconductors in terms of electrons and holes) and 1.1(b) (recall conduction processes at a p-n junction, the reasons for the difference in the conducting properties of a p-n diode in the different directions and explain the operation of an LED) of the specification. Since the question requires learners to demonstrate their knowledge of electronic procedures in a familiar context, it is classed as AO1 element 1b.

AO2: apply knowledge and understanding of ideas, techniques and procedures of electronics.

Component 1 Q5(b) requires the learner to draw the sinusoidal signal which has been modulated with a sinusoidal carrier. This question is based upon statement 1.7c (sketch, recognise and analyse the resulting waveforms for a sinusoidal carrier being amplitude and frequency modulated by a single frequency audio signal) of the specification. The drawing of the signal requires the learner to apply knowledge of electronic ideas and is therefore classed as AO2 element 1a.

Component 2 Q3(a) requires the learner to complete a block diagram to show how a counter is reset on every fifth pulse. This is based upon topic 2.1e (design systems that use a dedicated 4-bit counter and combinational logic to produce a sequence of events) of the specification. The questions ask learners to apply their understanding of procedures to reset the counter and the application of logic gates to give a sequence. This is therefore AO2 element 1b.

AO3: analyse problems and design, build, test and evaluate electronic systems to address identified needs. Only stands 1a and 1d can be assessed on written papers (all strands will be assessed in the NEA).

Component 2 Q5(b) This question has marks split between AO2 and AO3. The question requires learners to design a mixer to meet a specification and give an explanation to justify the design. This is based on topic 2.8c (analyse and design a mixer circuit based upon a summing amplifier) of the specification. One mark is allocated for applying knowledge of electronic ideas and are classed as AO2. Three marks are allocated for designing a system to a given specification and are classed as AO3 element 1b. One mark is also allocated for the explanation of the justification of the success of the design and is classed as AO3 element 1d.

Component 2 Q6(d) This question has marks split between AO1 and AO3. It requires learners to evaluate the advantages and disadvantages of using multimode and monomode optical fibres for the communications link on a university campus. This is based on topic 2.5b (… the relative advantages of single and multimode optical fibres in a communication network) of the specification. The two marks for demonstrating ideas of electronics are classed as AO1 element 1a. The four marks for evaluating the types of optical fibres for the university campus communication network is classed as AO3 element 1d.

Amplification of Content

This section gives amplification where needed to clarify specification content. The first column plan is taken directly from the specification. The second gives some additional elaboration of the electronics content column.

Learners will be required to draw together different areas of knowledge, skills and understanding from across the full course of study.

Synoptic questions will be set in both the Component 1 and Component 2 written exams. These questions will require learners to draw upon knowledge from ***both components***. Examples of synoptic questions are included in the Sample Assessment Materials.

Core Concepts

The Core Concepts are fundamental to the study of electronics. Topics within this section will be assessed in the Component 1 and 2 written exams and are essential for the successful completion of the NEA (Component 3).

1. SYSTEM SYNTHESIS

Spec Statement		Comment
(a)	recognise that electronic systems consist of inputs, processes and outputs and may include feedback	
(b)	represent complex systems in terms of sub-systems	
(c)	analyse and design system diagrams	Design, analyse or modify a block diagram of a system.

2. DC ELECTRICAL CIRCUITS

	Spec Statement	Comment
(a)	use standard circuit symbols to interpret and draw circuit diagrams	
(b)	define resistance R, as $R=\frac{V}{I}$, describe the effects of resistors in circuits and be able to use the equation $V = IR$	
(c)	use the equations to calculate the effective resistance of combinations of resistors connected in series and/or parallel $R = R_1 + R_2 + ...$ resistors in series $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + ...$ resistors in parallel $R = \frac{R_1 R_2}{R_1 + R_2}$ two resistors in parallel	
(d)	analyse circuits (based on a single power supply) using Kirchhoff's laws and Thevenin's theorem	Use Thevenin's theorem to draw equivalent circuits for a voltage divider consisting of two resistors or a sensing circuit and hence predict the effect of loading.
(e)	select appropriate values of resistor from the E24 series	
(f)	define capacitance, C as $C = \frac{Q}{V}$	
(g)	explain how capacitors can be used to form the basis of timing circuits and use the equations to calculate the effective capacitance of capacitors in series and parallel $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + ...$ capacitors in series $C = \frac{C_1 C_2}{C_1 + C_2}$ two capacitors in series $C = C_1 + C_2 + ...$ capacitors in parallel	

3. INPUT AND OUTPUT SUB-SYSTEMS

	Spec Statement	Comment
(a)	describe the use of photosensitive devices, ntc thermistors and switches in a voltage divider circuit to provide analogue signals	"Photosensitive devices" include LDRs, photodiodes and phototransistors. Appreciate that the current through a voltage divider should be at least ten times that drawn from the output.
(b)	determine experimentally, interpret and use characteristic curves for the above devices	
(c)	use the equation to calculate output voltages for a voltage divider $V_{OUT} = \frac{R_2}{R_1 + R_2} V_{IN}$	Recall that this equation assumes that no current is drawn from the output of the voltage divider.
(d)	explain how a Schmitt inverter can be used to provide signal conditioning	Describe the benefits of fast rise time for a signal.
(e)	design and construct sensing circuits with photosensitive devices, ntc thermistors and switches	The treatment will be limited to voltage divider circuits.
(f)	describe the use of a buzzer, a loudspeaker, a motor, a solenoid, a relay; a mechanical actuator (servo) and a seven-segment display in a system	

4. ENERGY AND POWER

	Spec Statement	Comment
(a)	recall that power is defined as the rate of doing work and use the relationship between energy, power and time $E = Pt$	
(b)	select and apply the rms voltage and current equations, $V_{rms} = \frac{V_0}{\sqrt{2}}$ and $I_{rms} = \frac{I_0}{\sqrt{2}}$, including power calculations in a sinusoidal AC circuit	
(c)	use the power relationships $P = VI = I^2R = \frac{V^2}{R}$ for AC and DC circuits	AC power calculations will not involve power factor.

Component 1 – Principles of Electronics

Synoptic questions will be set in the Component 1 written exam which require learners to draw upon knowledge from Component 2.

1. SEMICONDUCTOR COMPONENTS

Spec Statement		Comment
(a)	recall the conduction processes in n- and p-type semiconductors in terms of electrons and holes	Recognise the energy band diagram, showing conduction band, valence band and energy band gap, for: conductors, insulators, n-type and p-type semiconductors. Recall that, in a p-type semiconductor, conduction is mainly the result of the flow of holes, whereas, in an n-type semiconductor, it is mainly the result of the flow of free electrons. Describe electron/hole pair production / recombination. Describe effect of donor and acceptor impurities on conduction in silicon.
(b)	recall conduction processes at a p-n junction, the reasons for the difference in the conducting properties of a p-n diode in the different directions and explain the operation of an LED	Draw the energy band diagram for a p-n junction and show the effect of forward and reverse bias. Describe the LED as a p–n junction diode, which emits light when a suitable voltage is applied to the junction because electrons recombine with holes, releasing the energy as light. No knowledge of Planck's equation and calculations of wavelength of emitted light is needed.
(c)	recall the principles of operation of a photodiode	Recall that this is the reverse process to that delivering light in the LED. Here light is absorbed, creating an electron-hole pair. No knowledge of Planck's equation and calculations of wavelength of emitted light is needed.
(d)	explain the properties of an n-channel enhancement mode MOSFET in terms of the effects of bias voltage on the conducting channel (pinching)	Draw an idealised diagram of an unbiased n-channel enhancement MOSFET showing: n type source and drain regions, p type substrate, gate, source and drain terminals. Show / describe the effect of bias on this device.
(e)	describe the use of light-emitting diodes, silicon diodes and zener diodes in electronic systems and using data, including interpreting and sketching characteristic graphs to carry out relevant calculations on circuits containing these devices	Realise that the forward voltage for a silicon diode is approximately 0.7 V when the diode is conducting. Indicate the zener voltage V_Z and holding current $I_{Z(MIN)}$ on the characteristic graphs.

(f)	calculate series resistor values for LED circuits and select appropriate zener diodes	Select zener diodes, given data on zener voltage and power rating.
(g)	describe the use of n-channel enhancement mode MOSFETs and npn bipolar transistors in switching circuits, using data to select suitable components for circuits	Describe the switching action of an npn transistor by making reference to its voltage transfer characteristic. Know that V_{BE} depends on I_B and is approximately 0.7 V when the transistor is conducting. Recognise that MOSFETs have a very high input resistance. Understand that r_{DS} decreases from a very high value to a very low value as V_{GS} is increased and is at a minimum value, called r_{DSon}, at saturation. Compare the performance of MOSFET and transistor switches. State the need for diode protection for transistors and MOSFETs.
(h)	define g_M as the gradient of an I_D-V_{GS} graph	
(i)	select and apply the equations $I_C = h_{FE} I_B$ bipolar transistor $I_D = g_M(V_{GS} - 3)$ MOSFET $P = I_D^2 r_{DSon}$ power dissipated in a MOSFET	Recall conditions necessary for these equations to be valid. Understand that an enhancement mode MOSFET does not conduct until the gate threshold voltage V_{GSth} is reached. In calculations V_{GSth} is assumed to be 3 V.

2. LOGIC SYSTEMS

Spec Statement		Comment
(a)	identify and use NOT; 2 and 3-input AND, NAND, OR, NOR, XNOR and XOR logic gates	The 3-input XOR gate is treated as two 2-input XOR gates cascaded together, i.e. the first two signals are fed into a 2-input XOR gate, with its output fed into a second 2-input XOR gate together with the third signal. The resulting truth table is that of a 74LVC1G386 logic gate. (Output is high when a single input is high or when all three inputs are high.) The 3-input XNOR is considered as the inverse of this 3-input XOR gate. Draw and interpret graphs of the output signal from a logic gate given the input signals.
(b)	construct, recognise and use truth tables for these gates and simple combinations of them	Recall use of mechanical switches with resistors and pulse generators to provide inputs for logic systems. Recall use of an LED and resistor to indicate the output state of a logic system.
(c)	use combinations of one or more types of gate to perform other logic functions including NAND-gate simplification	Show how the following logic gates can be made up from NAND gates: NOT, 2 input AND, OR and NOR gates. Implement a logic system using only NAND gates and identify redundant gates in such a system.
(d)	simplify logic systems using Boolean algebra, Karnaugh maps and multiplexers	Draw a Karnaugh map for a logic system with up to four inputs and use it to minimise the number of gates required. Design and analyse a system with up to four inputs using a multiplexer as a programmable logic system.
(e)	design and construct circuits containing logic gates, with consideration to sourcing, sinking, pull-up and pull-down resistors	Translate a design specification into a truth table. Design and test a system, with up to four inputs from a specification. Generate the Boolean expression for a system [with up to four inputs] from a logic diagram or a truth table.
(f)	use de Morgan's theorem to simplify a logic system $\overline{A+B}=\overline{A}.\overline{B}$ $\overline{A.B}=\overline{A}+\overline{B}$	Apply de Morgan's theorem to simplify a logic system having up to three inputs.
(g)	use the Boolean identities $A.1=A,\ A.0=0,\ A.A=A,$ $A.\overline{A}=0,\ A+1=1,\ A+0=A,$ $A+A=A,\ A+\overline{A}=1$	
(h)	select and apply the Boolean identities $A+\overline{A}.B=A+B$ $A.B+A=A.(B+1)=A$	

3. OPERATIONAL AMPLIFIERS

Spec Statement		Comment
(a)	recall the characteristics of an ideal op-amp and be aware that these may be different for a typical op-amp	Recall the following characteristics of an ideal op-amp: • infinite open loop gain • infinite input impedance • zero output impedance • infinite slew-rate • infinite common-mode rejection ratio.
(b)	recognise that the voltage difference between the two inputs of an op-amp with negative feedback is virtually zero (resulting in a virtual earth if one of the inputs is at 0 V) provided the output is not saturated	
(c)	explain the use of an op-amp in a comparator circuit	
(d)	recall how the output state of a comparator depends upon the relative values of the two input states and design comparator switching circuits	
(e)	recall and apply the conditions for the balance of a bridge circuit	A comparator circuit often receives input signals from the centres of two voltage dividers, making up a bridge circuit.
(f)	define the voltage gain, G, of an amplifier as $G = \frac{V_{OUT}}{V_{IN}}$ and be able to select and apply the equation	
(g)	draw, recognise and recall the characteristics of the following op-amp circuits: • non-inverting amplifier • inverting amplifier • summing amplifier • comparator • voltage follower circuit	Draw and interpret response graphs of inverting and non-inverting amplifiers for AC and DC input signals.
(h)	select and apply the following equations for op-amp circuits: non-inverting amplifier $G = 1 + \frac{R_F}{R_1}$ inverting amplifier $G = -\frac{R_F}{R_{IN}}$ summing amplifier $V_{OUT} = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + ...\right)$	

(i)	select and apply the following equations for op-amp circuits: comparator $V_{OUT} = V_S$ for $V_+ > V_-$ $V_{OUT} = -V_S$ for $V_+ < V_-$ voltage follower circuit $V_{OUT} = V_{IN}$	
(j)	relate the input impedance of an op-amp to its configuration	Recall that the input impedance of a non-inverting amplifier is equal to that of the op-amp it uses. Recall that the input impedance of an inverting amplifier is approximately equal to that of its input resistor.
(k)	recall that the bandwidth is the frequency range over which the voltage gain is greater than $\frac{1}{\sqrt{2}}$ of its maximum value and estimate this bandwidth from a frequency response curve and use the gain-bandwidth product (unity gain bandwidth) to estimate bandwidth	
(l)	design single stage amplifiers based on inverting and non-inverting voltage amplifiers to achieve a specified voltage gain or bandwidth	Applications could include using calibrated sensors to provide a dc input to a non-inverting amplifier.
(m)	explain how clipping and slew-rate can lead to distortion	Recognise clipping distortion, and describe how it can be reduced by increasing the supply voltage, reducing the gain or reducing input amplitude. Recognise slew rate distortion for a step input and a high frequency sinusoidal input.
(n)	select and apply the equations $\text{slew rate} = \frac{\Delta V_{OUT}}{\Delta t}$ definition of slew rate $\text{slew rate} = 2\pi f V_P$ minimum slew-rate for distortion free sinusoidal signal	

4. SIGNAL CONVERSION

Spec Statement		Comment
(a)	explain the need for signal conversion between analogue and digital form in communications and microprocessors	Describe the need for signal conversion between analogue and digital form in areas such as communication systems and microprocessor systems. Compare the merits of analogue and digital communication.
(b)	describe how an op-amp summing amplifier can be used as a DAC to convert a digital signal into an analogue signal	Recall the factors affecting the resolution of the DAC.
(c)	analyse and design a DAC based upon an op-amp summing amplifier to meet a given specification	
(d)	describe how comparators can be used as an ADC to convert an analogue signal into a digital signal	
(e)	describe the process of digitising audio signals and explain the effects of sampling rate and resolution	
(f)	analyse and design a flash converter ADC based on comparators and priority encoders to meet a specification and describe the factors affecting the resolution	The circuit will include a subsystem to indicate overflow (when the input signal exceeds the input voltage range of the ADC). Analyse and design a priority encoder to meet a given specification.
(g)	select and apply the equation for calculating the resolution of a n-bit flash converter $\text{resolution} = \frac{\text{i/p voltage range}}{2^n}$	
(h)	compare the difference of a digital ramp ADC and a flash ADC	Considerations: speed of conversion, resolution, circuit complexity, cost.

5. AC CIRCUITS AND PASSIVE FILTERS

Spec Statement		Comment
(a)	use V-t, I-t and P-t graphs for resistive loads	Obtain amplitude, period, frequency, rms values (for sinusoidal signals), mark:space (for square wave signals) and energy delivered in a set time.
(b)	describe the relationship between rms and peak values	Treatment limited to sinusoidal signals.
(c)	select and apply the equations to calculate the reactance of capacitors and inductors and the impedance for a series circuit $X_C = \frac{1}{2\pi f C}$ $X_L = 2\pi f L$ $Z = \sqrt{R^2 + X^2}$	Treatment limited to sinusoidal signals.
(d)	draw, recognise and interpret the output of RC passive filters using linear-log and log-log output graphs and describe the advantage of buffering passive filters	Understand that a complex wave is constructed from a fundamental frequency plus a number of harmonic frequencies. For a given signal, draw the frequency spectrum, after it passes through an ideal filter of specified characteristics.
(e)	recognise, analyse, design and draw circuits for high-pass and low-pass passive RC filters and passive LC band-pass filters	
(f)	select and apply the equations $f_0 = \frac{1}{2\pi\sqrt{LC}}$ resonant frequency for LC filters $R_D = \frac{L}{r_L C}$ dynamic resistance of a resonant circuit $Q = \frac{f_0}{\text{bandwidth}} = \frac{2\pi f_0 L}{r_L}$ Q-factor	Recall that resonance occurs in a parallel LC network when $X_C = X_L$ and hence calculate the resonant frequency. Appreciate that, in practical inductors, their resistance r_L has the effect of lowering the value of f_0. Calculate the output voltage of an unloaded filter at resonance, using the dynamic resistance formula. Know that the Q-Factor indicates the selectivity of a band pass filter. Calculate the Q-Factor, either from the frequency response graph, or from component values.

6. COMMUNICATIONS SYSTEMS

	Spec Statement	Comment
(a)	recall that communication is the transfer of meaningful information from one location to another	
(b)	recall the structure of a simple communication system consisting of: information source, transmitter/encoder, transmission medium, amplifier/regenerator receiver/decoder and information destination	Understand the following terms applied to a communications system: • analogue and digital signals • carrier • encoding / decoding • modulation / demodulation • gain / attenuation • base (signal) bandwidth • broadcast bandwidth • noise / distortion • error detection, error correction.
(c)	recall and explain the relationship between bandwidth, data rate and information-carrying capacity and select and apply the equations $N_{CH} = \frac{\text{available bandwidth}}{\text{channel bandwidth}}$ $\text{maximum data rate} = 2 \times \text{available bandwidth}$	Understand that the available bandwidth of the transmission media and the channel bandwidth can be specified in terms of a frequency range or a wavelength range. N_{CH} refers to the number of channels.
(d)	explain the need to multiplex a number of signals onto one transmission medium and describe the principles of frequency and time division multiplexing	Understand the following terms applied to a communications system: • multiplexer / demultiplexer • time division multiplexing • frequency division multiplexing.
(e)	describe the role of filters in communication systems	
(f)	use the decibel scale to express power gain in amplifiers/attenuation in transmission media and select and apply the equation $G_{dB} = 10\log_{10}\frac{P_{OUT}}{P_{IN}}$ gain in decibels	
(g)	differentiate between noise and distortion	
(h)	calculate the total gain in a communication system given the power gain or attenuation of its component parts	
(i)	state what is signal to noise ratio and select and apply the equations $SNR_{dB} = 10\log_{10}\frac{P_S}{P_N} = 20\log_{10}\frac{V_S}{V_N}$ signal to noise ratio	
(j)	state what signal attenuation is and describe the significance of signal attenuation (in dB) for the signal-to-noise ratio	Understand that the signal-to-noise ratio degrades down a transmission line, and that regeneration restores the original signal.

7. WIRELESS TRANSMISSION

	Spec Statement	Comment
(a)	recall and explain the use of the different regions of the radio spectrum for the transmission of data, including in terms of bandwidth requirements and available frequency channels	Distinguish between the following modes of transmission and relate them to transmission frequency: surface waves, line-of-sight, ionospheric (skywaves).
(b)	describe and explain the use of amplitude modulation and frequency modulation and select and apply the equations $m = \frac{(V_{max} - V_{min})}{(V_{max} + V_{min})} \times 100\%$ depth of modulation $\beta = \frac{\Delta f_c}{f_i}$ modulation index $\text{Bandwidth} = 2(\Delta f_0 + f_i) = 2(1+\beta)f_i$ transmitted FM bandwidth $c = f\lambda$ wave speed	Draw and analyse graphs to show the frequency spectrum for a sinusoidal carrier, amplitude modulated by an audio signal. Recall that an FM-modulated carrier produces an infinite number of sidebands. Recall that frequency deviation, Δf_c, is the maximum change in frequency of the carrier from its base value f_c. Recall that the modulation index, β, is the FM equivalent of depth of modulation. Appreciate that almost all the power of a transmitted FM signal is contained within a bandwidth of $2(1 + \beta) f_i$. An example of the use of the wave speed formula would be to calculate the frequency from the wavelength of an optical signal.
(c)	sketch, recognise and analyse the resulting waveforms for a sinusoidal carrier being amplitude and frequency modulated by a single frequency audio signal	Draw and analyse graphs to show the resulting waveform for a sinusoidal carrier, amplitude modulated by an audio signal, to a given depth of modulation, m. Draw and analyse graphs to show the resulting waveforms for a sinusoidal carrier which is frequency modulated by a single frequency audio signal.

8. INSTRUMENTATION SYSTEMS

Spec Statement		Comment
(a)	draw and recognise an op-amp difference amplifier circuit and select and apply the equation $V_{OUT} = V_{DIFF}\left(\frac{R_F}{R_1}\right)$	
(b)	analyse and design instrumentation amplifiers based upon the op-amp difference amplifier circuit	Recall and explain the significance of the ideal properties of an instrumentation amplifier – high input impedance and high common-mode rejection ratio.
(c)	describe the use of bridge circuits with thermistors and strain gauges	Recall the advantages of a bridge circuit compared to a simple voltage divider circuit.
(d)	describe the use of the slotted discs (for sensing rotational speed) and encoded discs (for sensing angular position)	
(e)	compare the Gray coding of encoded discs with binary coding	Recall Gray code (up to three bits) and explain its use in encoded discs.
(f)	design logic system to process the output of slotted and encoded discs	

Component 2 – Application of Electronics

Synoptic questions will be set in the Component 2 written exam which require learners to draw upon knowledge from Component 1.

1. TIMING CIRCUITS

	Spec Statement	Comment
(a)	use the equation for the time constant (T) for an RC circuit: $T = RC$	
(b)	select and apply the exponential charging and discharging equations: $V_C = V_0\left(1 - e^{-\frac{t}{RC}}\right)$ for a charging capacitor $V_C = V_0 e^{-\frac{t}{RC}}$ for a discharging capacitor and use 0.69 RC as the half time and 5 RC as an approximation to estimate effective charging and discharging times	Sketch capacitor charge and discharge curves for voltage and current.
(c)	select and apply the equations $t = -RC\ln\left(1 - \frac{V_C}{V_0}\right)$ charging capacitor $t = -RC\ln\left(\frac{V_C}{V_0}\right)$ discharging capacitor	
(d)	calculate values of T, R and C for a charging / discharging capacitor by using a graph (including log graphs)	
(e)	use a RC circuit in debouncing switches	
(f)	recall the properties of monostable circuits	Recall that a monostable circuit has one stable and one unstable state.
(g)	explain the use of a monostable circuit in conjunction with a RC network in a time-delay circuit	State the advantage of adding a buffer to the output of the RC network.
(h)	recall the properties of an astable circuit and its use as a pulse generator	Recall that an astable circuit has two unstable states.

(i)	explain the operation, draw and design the circuit of an astable circuit based upon a Schmitt trigger and select and apply the approximation $f \approx \frac{1}{RC}$, where f is the operating frequency	
(j)	draw and analyse circuits for monostable and astable circuits based upon a 555 timer IC, and select and apply the following equations to calculate their characteristics including pulse duration, frequency, mark-space ratio $f = \frac{1}{T}$ frequency, period relationship $T = 1.1RC$ 555 monostable $t_H = 0.7(R_1 + R_2)C$ mark time of a 555 astable circuit $t_L = 0.7R_2C$ space time of a 555 astable circuit $f = \frac{1.44}{(R_1 + 2R_2)C}$ frequency of a 555 astable circuit $\frac{T_{ON}}{T_{OFF}} = \frac{R_1 + R_2}{R_2}$ mark/space ratio of an astable	Draw and interpret output graphs for monostable and astable circuits. T is the time period.

2. SEQUENTIAL LOGIC SYSTEMS

Spec Statement		Comment
(a)	design and describe the action of a Set-Reset ($\overline{S}\overline{R}$) latch based on NAND gates	Use a truth table sequence to describe the action of the bistable.
(b)	describe the significance of propagation delays in sequential systems	
(c)	construct and use timing diagrams to explain the operation of sequential logic circuits	
(d)	recall the characteristics and uses of the inputs and outputs of D-type flip-flops for: • transition gates • frequency divider circuits • asynchronous counters • parallel-in-series-out (PISO) registers • series-in-parallel-out (SIPO) registers • synchronous counters	Draw a timing diagram to illustrate how a transition gate can be used to produce edge-triggering. Design a transition gate to a given specification. Design up and down counters based on D-type flip-flops (up to 4-bit). Design 4-bit modulo-n counters and binary coded decimal (BCD) counters and draw the resulting timing diagrams. Recognise, analyse and design circuits for parallel-in serial-out (PISO) registers and serial-in-parallel-out (SIPO) registers and draw the resulting timing diagrams. Explain how synchronous counters overcome the high counting speed limitation of ripple counters.
(e)	design systems that use a dedicated 4-bit counter and combinational logic to produce a sequence of events	Design dedicated 4-bit modulo-n counters and binary coded decimal (BCD) counters and draw the resulting timing diagrams.
(f)	design and analyse a 2 digit decimal counting system	Describe the use of decoder/drivers and 7-segment displays. Decoders are available integrated with BCD counters in a single IC or separately.
(g)	convert between binary, decimal, hexadecimal and binary-coded decimal (BCD) number systems	
(h)	design sequence generators based on D-type flip-flops configured as synchronous counters, use state diagrams and explain the significance of stuck and unused states, including Boolean manipulation to produce simpler solutions	Design a synchronous counter to meet a given specification. Analyse a synchronous counter (up to three bits) to obtain the state diagram for the sequence it produces. Draw the state diagram for a synchronous counter given a system specification. Manipulate unused ('don't care') states to produce simpler solutions

3. MICROCONTROLLERS

Spec Statement		Comment
(a)	analyse and design flowchart programs to program microcontrollers	Questions are limited to designing a flowchart to meet a given specification, analysing a given flowchart, modifying a given flowchart or completing a template for a flowchart. Use the following operations in flowcharts: input/output, counting, branching, testing, time delay and arithmetic operations.
(b)	recall and describe the structure of a PIC microcontroller as programmable assemblies of memory, input ports, output ports, CPU, clock and reset	Write and analyse given code to configure the ports as input or output ports, using the data direction registers.
(c)	recall and explain the use of interrupts to allow an external device to be serviced on request	Draw a circuit diagram to show how an external device can be connected to a PIC microcontroller to cause an interrupt. Use a vector address to point to an interrupt service routine. Configure the INTCON file register to enable an external interrupt. Recognise the need to protect the contents of the working register when writing an interrupt service routine. Recognise the need to clear the interrupt flags when writing an interrupt service routine.
(d)	recall and describe the application of a PIC microcontroller	Examples include automotive technology, household appliances, 'internet of things' etc.
(e)	analyse, design and program PIC microcontroller-based circuits using assembler language	Devise and analyse code using the following instructions: addlw, andlw, bcf, bsf, btfsc, btfss, call, clrf, comf, decfsz, goto, incf, iorlw, movf, movlw, movwf, nop, retfie, return, sublw. Incorporate given subroutines into program code.

4. DIGITAL COMMUNICATIONS

Spec Statement		Comment
(a)	analyse and design Schmitt trigger circuits to regenerate a digital signal	Design inverting and non-inverting Schmitt trigger circuits to meet a given specification. Understand that the signal-to-noise ratio degrades down a transmission line, and that Schmitt trigger circuits are used to regenerate digital signals.
(b)	analyse and draw graphs to illustrate pulse modulation techniques (pulse width modulation (PWM), pulse amplitude modulation (PAM), pulse position modulation (PPM))	
(c)	draw a block diagram for and describe the operation of a pulse code modulation (PCM) communication system consisting of: transmitter low pass filter, sampling gate, sampling clock, ADC, PISO shift register, PISO clock and receiver Schmitt trigger, SIPO shift register, SIPO clock, DAC, low pass filter	
(d)	use the relationship between required sampling frequency to the highest frequency in the signal and Nyquist theorem	
(e)	describe how time division multiplexing (TDM) can be used to improve the user capacity of a PCM communications link	
(f)	state the limitation on the number of channels that can be incorporated into a PCM communications link, using TDM and use given data to calculate how many channels can be incorporated into a PCM communications link, using TDM	Calculate the number of channels either from first principles or from the formula: $\text{Number of channels} = \dfrac{\text{sampling period}}{\text{No. of bits} \times \text{PISO Period}}$ Questions could be set to determine any one of the four variables given the other three.

5. OPTICAL COMMUNICATION

Spec Statement		Comment
(a)	describe how the refractive properties of glass allow signals to be transmitted over long distances in optical fibres	Describe conditions leading to total internal reflection. Recall that signals in optical fibres are immune to e-m radiation.
(b)	describe the effects of dispersion, attenuation and radiation losses in optical fibre communication and the relative advantages of single and multi-mode optical fibres in a communication network	Recall the structure of an optical fibre (core, cladding, coating). Appreciate that wave-division multiplexing (WDM) uses similar principles as frequency division multiplexing (FDM) and allows a number of optical signals to be multiplexed onto a single optical fibre.
(c)	describe the principles of operation of circuits for converting between electrical and optical signals	Recall that a simple transmitter circuit incorporates a LED light source and a transistor or MOSFET. Recall that a simple receiver circuit incorporates a photodiode and op-amp, configured as a current to voltage converter.
(d)	describe the use of LED and laser light sources in an optical fibre transmitter	Contrast the following properties: power output, spectral width, speed and cost. Perform calculations relating energy delivered and power rating of a laser/LED.

6. MAINS POWER SUPPLY SYSTEMS

	Spec Statement	Comment
(a)	recall the use of diodes for half-wave and full wave rectification	Draw and explain the use of diodes in half-wave and full-wave bridge rectifiers. Calculate the peak value of the output voltage of half-wave and full-wave rectifiers, given the rms input voltage.
(b)	describe the effect of capacitors and loads on the output of a simple power supply	Draw graphs to show the effect of a capacitor and the effect of load resistance on ripple voltage for a simple power supply.
(c)	select and apply the ripple voltage equation $V_r = \frac{I}{f_r C}$	
(d)	design zener regulated power supplies and draw graphs to show the effect of loading	Design a simple power supply consisting of a zener diode and current-limiting resistor connected as a voltage divider. Calculate suitable values for the current-limiting resistor and the maximum value of output current available.
(e)	distinguish between load regulation and line regulation	
(f)	analyse and design a voltage regulator based upon a zener diode, a transistor emitter follower and a non-inverting amplifier	Questions can be set on a zener diode regulator and emitter follower only (i.e. without the non-inverting amplifier subsystem.) Recall that $V_{OUT} = V_{IN} - 0.7$ for an emitter follower
(g)	select and apply the gain equation $V_L \approx V_Z\left(1 + \frac{R_F}{R_1}\right)$	

7. HIGH POWER SWITCHING SYSTEMS

	Spec Statement	Comment
(a)	describe the advantages of using thyristors and triacs to switch high power DC/AC loads respectively, compared to using a transistor or a relay	Advantages include switching speed and lack of moving parts – eliminating friction and wear.
(b)	recall the general thyristor characteristics, the conditions under which a thyristor conducts and explain the significance of the following terms: holding current, minimum gate voltage, minimum gate current	
(c)	design DC thyristor switching circuits and explain the process of capacitor commutation	
(d)	draw the circuit diagram and analyse graphs for an AC phase control circuit, using a RC network, a triac and a diac	Sketch voltage/time graphs for the waveforms for the capacitor, triac and load.
(e)	select and apply the equation $\phi = \tan^{-1}\left(\frac{R}{X_C}\right)$ to calculate the phase shift between supply voltage and capacitor voltage	

8. AUDIO SYSTEMS

Spec Statement		Comment
(a)	recall the structure of a simple audio system based upon preamplifiers, a mixer, tone controls, a power amplifier and output loudspeaker	
(b)	analyse and design a multi-stage voltage preamplifier to meet bandwidth and gain requirements	Describe the function of decoupling capacitors.
(c)	analyse and design a mixer circuit based upon a summing amplifier	
(d)	describe and explain the operation of first order active filters (bass boost, treble boost, bass cut, treble cut) based upon an op-amp inverting amplifier and select and apply the equation to calculate the break frequency $f_b = \frac{1}{2\pi R C}$	Identify the type of filter from its frequency response graph. Design first order active filter circuits based on an op-amp inverting amplifier, given a specification or a graph of the frequency response of the filter. Analyse the performance of these first order active filters, given the circuit diagram or the frequency response graph of the filter.
(e)	recall and apply the maximum power transfer theorem	
(f)	draw circuits for and recall the properties of emitter and source follower power amplifiers ($V_{OUT} \approx V_{IN} - 0.7$ for an emitter follower and $V_{OUT} \approx V_{IN} - 3$ for source follower)	Recall that the input impedance of an emitter follower is approximately equal to $h_{FE}\,R_E$. Recall that the input impedance of a source follower is extremely high. Recall that the output impedance of an emitter follower is usually lower than that of a source follower.
(g)	draw circuits for and recall the properties of push-pull power amplifiers consisting of either emitter or source followers and select and apply the equation $P_{MAX} = \frac{V_S^2}{8R_L}$ push-pull power amplifier	
(h)	analyse and draw graphs of the waveforms for first order active filters, emitter and source follower power amplifiers and push-pull power amplifiers	Calculate the break frequency for a given circuit or from a frequency response graph.
(i)	describe cross over distortion in push-pull amplifiers and its removal using negative feedback	Removal of cross over distortion will be limited to circuits using an op-amp.

Extended system design and realisation tasks (NEA)

See sections 2.3 and 3.2 of the specification (AS/A Level Electronics) and e-Submission for information on how to upload work for moderation.

NEA task forms (available on AS/A Level Electronics under NEA) must be completed for each learner and submitted with reports. The task form gives the assessment criteria for the Component. It is also used to record learner details, details of the project and marks awarded. The task form includes a declaration that **must be signed by both the learner and the teacher**. Note that declarations must be signed for **all** learners – not just those selected for moderation.

Further guidance for the NEA is given below:

General Guidance
Learners must select their **own problem** on which their project will be based. This should result in a wide range of different projects being produced by each centre.

Projects should be neither under- nor over-ambitious. The teacher must agree and sign off the problem on learners' tasks sheets, ensuring that it is appropriate for the ability and interests of the learner.

Circuits may be constructed on prototype board, strip board or printed circuit board. The layout and mounting of components and wiring should be neat, logical and allow testing and fault finding of the system.

Learners should progress through the following 4 stages and produce reports in 4 sections corresponding to these (see later section on Project Reports).

System Planning
When a problem has been chosen, learners should produce a design specification in both qualitative and quantitative terms. For Task 1 there should typically be at least 3 of each, including 2 or more detailed realistic **measurable** parameters. For Task 2, typically at least 4 of each, including 3 or more detailed realistic **measurable** parameters. These could include parameters such as temperature ranges, pressure etc. needed for their chosen application.

Specifications should contain realistic and **justified** numerical parameters, against which the performance of the final circuit can be judged. Parameters should be based on the required operation of the system. Parameters such as maximum current, supply voltage or component properties would **not** be valid, without justification.

For Task 2, learners should carry out appropriate research to enable them to produce the specification. This could include research of parameters such as temperature ranges, pressure etc. needed for their chosen application and possibly also research of similar products available for comparison. Research of standard component parameters, e.g. logic ICs or circuits included in the specification such as 555 timers, are **not** classed as relevant research.

System Development
The system should be developed as a number of sub-systems, individually tested and evaluated before being incorporated into the complete system. All test results should be recorded as tables and/or graphs, where appropriate. Photographs of test equipment showing measurement or simulations can also be included as an effective way of showing evidence of testing.

For Task 2 projects that include microcontrollers, a subroutine / procedure can be considered as **one** sub-system as long as a specification is provided for it and it can be tested and evaluated in a similar fashion to a component based sub-system.

System Realisation
The complete system should be fully tested and test results recorded. When necessary, learners should attempt to make any modifications needed for their circuit to meet the specification and produce a final set of performance parameters for the completed system.

A photograph of the finished circuit must be included in this section. No other form of evidence (e.g. videos) should be included.

Evaluation
Learners should, by referring to their test results, evaluate the final system against the design specification and suggest further developments. Further developments should relate to improving the operation of the system rather than superficial changes to circuits.

Project reports
Reports should be presented in the 4 sections described above: System planning, System Development, System Realisation and Evaluation.

Learners should aim to ensure that evidence for each of the assessment criteria (given on the task form) is presented in the appropriate section of each report.

Assessment
The NEA is internally marked by teachers using the assessment criteria given on the task form. The criteria descriptor which best matches the candidate's work should be identified and awarded. Criteria partially achieved can be taken into account when determining the mark awarded.

The **criteria achieved, partially achieved** and **not achieved** for each section of each task, **must be clearly recorded on the candidates' task form** – see exemplars with completed task forms on Portal.

Marks can only be awarded when there is supporting evidence. **Learners' reports must be annotated to show where each of the criteria have been achieved and awarded** – see exemplars on Portal. It is helpful if teachers comment on the extent to which the circuit worked and met the specification.

Marks can only be awarded for learners' own work. Any assistance that goes beyond the guidance given in the specification must be recorded on the task form and taken into account when marking. The centre is responsible for carrying out internal standardisation where two or more teachers have been involved in the marking of the work submitted.

Submission of moderation samples
Once all learners' work has been marked, the marks must be entered into the online IAMIS system and sent electronically to WJEC. The online system will then select and return the candidates identified for the moderation sample.

The moderation samples must be in electronic form (scanned if necessary) and uploaded to the IAMIS system. Each sample must be uploaded as a single pdf document with the candidate number included as part of the filename. Guidance can be found on and e-Submission.

Each sample must include:

- a completed task form (signed by both the candidate and teacher, showing which criteria have been achieved, the marks awarded for each section and the total marks)
- the 2 task reports, each in 4 sections (see above), clearly identified and annotated by teachers to show where the assessment criteria awarded, have been achieved
- photographic evidence of the completed physical systems.

Further specific guidance

Task 1
This task requires learners to produce a program in **assembly language** and to run and test the program on a microcontroller IC. **No other programming languages can be used.**

Suitable systems to use for this task include PICAXE, Matrix and Microchip. A free online course on assembly for PIC microcontrollers is available: ASM4PICs - Course.

Programs can be developed and initial testing carried out using a development board such as Arduino **but the final program must be run by a microcontroller IC**, mounted on a circuit board.

Program templates are provided on AS/A Level Electronics. These include the necessary setting up instructions and some timing subroutines. These can be used by learners and their own code inserted where indicated. If an alternative program template, provided by the centre is used, a blank copy of this must be included with learners' reports. This will enable moderators to identify the code learners have produced themselves.

The report must include the program flowchart, a listing of the program, a description of how the program works, details of testing of the program and a photograph of the final circuit with microcontroller IC mounted.