GCE AS

eduqas
Part of WJEC

WJEC Eduqas GCE AS in ELECTRONICS

ACCREDITED BY OFQUAL
DESIGNATED BY QUALIFICATIONS WALES

GUIDANCE FOR TEACHING

Teaching from 2017
For award from 2018

wjec
cbac

Contents

Introduction

The WJEC Eduqas AS in 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 AS 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 AS in 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 Eduqas 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 AS in 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 Model

Component 1 should be taught alongside practical work and Component 2 (NEA). Practical work should be taught as an integral part of the theory. The first four sections can be taught when required in the other sections of Component 1.

<table>
<tr><td>Year</td><td colspan="7"></td></tr>
<tr><td rowspan="4">12</td><td colspan="7">Component 1</td></tr>
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DC Electrical circuits
Input and output sub-systems
Energy and power</td></tr>
<tr><td>Semiconductor components</td><td>Logic systems</td><td>Operational amplifiers</td><td>Timing circuits</td><td>Sequential logic systems</td><td>Microcontrollers</td><td>Mains power supply systems</td></tr>
<tr><td colspan="7">Practical work and Component 2 (NEA)</td></tr>
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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 the ideas, techniques and procedures of electronics.

Component 1 Q1(a) asks learners to define capacitance. This question is based upon statement 1.2(f) define capacitance … of the specification. Since the question requires learners to demonstrate their knowledge of capacitance in a familiar context, it is classed as AO1 strand 1a. This is also classed as knowledge in isolation.

Component 1 Q3(a) asks learners to give simplify expressions. This question is based on the statement 1.6(d) simplify logic systems using Boolean algebra… and statement 1.6(f) use de Morgan's theorem to simplify a logic system of the specification. Since the question requires learners to demonstrate their knowledge of the algebra simplification techniques, this is classed as AO1 strand 1b.

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

Component 1 Q6(c) asks learners to explain what happens to the output voltage when a light beam is broken to the input of a sub-system. This question is based on the statement 1.2(a) use standard circuit symbols to interpret… circuit diagrams; statement 1.3(a) describe the use of photosensitive devices… in a voltage divider circuit to provide analogue signals; statement 1.3(b) … interpret and use characteristic curves for the above devices and statement 1.7(d) recall how the output state of a comparator depends upon the relative values of the two input states and design comparator switching circuits. This requires the application of ideas in unfamiliar context, it is classed as AO2 strand 1a and it also requires the application of procedures to determine the action of the comparator and is hence AO2 strand 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 1 Q9(a) requires learners to design a circuit for a non-inverting amplifier based on an op-amp with some set details. AO3 1a requires learners to analyse problems and design electronic systems to address identified needs. This is therefore classed as AO3 strand 1a.

Component 1 Q7(a) requires learners to evaluate why feedback is used in voltage amplifiers built from op-amps used in audio an amplifier system. AO3 1d requires learners to analyse problems and evaluate electronic systems to address identified needs. This requires the learners to evaluate the electronic systems and hence classed as AO3 strand 1d.

Component 1

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 the LDR and the phototransistor. 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.

5. SEMICONDUCTOR COMPONENTS

Spec Statement		Comment
(a)	describe the use of light-emitting diodes, silicon diodes and zener diodes in electronic systems	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.
(b)	carry out relevant calculations on circuits containing these devices using data, including interpreting and sketching characteristic graphs including calculating series resistor values for LED circuits and selecting appropriate zener diodes	Select zener diodes, given data on zener voltage and power rating.
(c)	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 a 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.
(d)	define g_M as the gradient of an I_D-V_{GS} graph	
(e)	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.

6. 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. 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 $A+\overline{A}.B = A+B$ $A.B+A = A.(B+1) = A$	

7. 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 of free sinusoidal signal	

8. 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.

9. SEQUENTIAL LOGIC SYSTEMS

Spec Statement		Comment
(a)	design and describe the action of a Set-Reset ($\overline{SR}$) 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	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.
(e)	design systems that use a dedicated 4-bit counter and combinational logic to produce a sequence of events	
(f)	design and analyse a 2 digit decimal counting system	Describe the use of decoders and seven-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	

10. 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.

11. 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.

Component 2

The NEA is an integral part of the WJEC Eduqas AS in Electronics and contributes 20% to the final assessment. This component requires each learner to complete three tasks independently. The tasks build on the concepts studied throughout the specification and the requirement to relate practical circuit design and realisation gained from the study of Component 1.

Task 1 (20 marks) – involves the development of a digital system.

Task 2 (20 marks) – involves the development and investigation to test an analogue system.

Task 3 (20 marks) – involves the development of a microcontroller system programed via a flowchart.

Learners should be encouraged and supported to select tasks in which they are interested and which are neither under nor over ambitious. The focus for each learner's task must be signed off by the teacher. The teacher should discuss the proposed focus of the task with the learner, considering the requirements of the assessment and the ability and interests of the individual learner. The teacher must be satisfied that the suggested focus has the potential for the individual learner to:

- analyse the problem and derive a design specification;
- develop and test a range of sub-systems;
- develop, realise and test a final physical system;
- evaluate the final system against the design specification and suggest improvements.

This will help ensure the task is at a suitable level for the learner concerned and will provide that individual with a level of challenge that is appropriate to their abilities, in the context of the requirements of an AS in Electronics qualification.

Having decided on a context for each task, the learner should undertake appropriate research so that a list of performance parameters (specification) can be produced. It is expected that the specification will contain realistic numerical values against which the final performance of the work can be judged.

In each task the overall system should be developed as a number of sub-systems which can be individually and/or incrementally tested.

The learner should fully document the development of each task in a report. It is the evidence contained within this report and the system produced upon which each task should be marked and assessed. The report should contain evidence for each task of the following sections:

- System planning – including analysis of the problem and a design specification
- System development – including the development of the system in terms of sub-system, annotated circuit diagrams and description of testing each sub-system and the recording of results

- System realisation – including annotated block and circuit diagrams; evidence of layout planning; description of testing of complete systems and the recording of results

- Evaluation – including a detailed evaluation of the system against the design specification and suggestions for improvement.

The report should be presented in a logical order that is easy to read and understand. It should contain an acknowledgement of all sources of information and help. Photographs of the complete physical system must be included in the report.

In each task the system should be fully tested when the project is complete. The testing should be documented with results being displayed in tables and graphs, where appropriate. These tests will enable the learner to assess the system and identify faults and limitations. The learner should then evaluate the final system against the design specification and suggest further developments.

Task 1

Task 1 requires learners to design and realise a digital system. Initial sub-systems may be simulated and tested on CAD programs or development boards to prove the sub-systems before final realisation of a physical circuit of the complete system for testing.

Task 2

Task 2 requires learners to investigate an analogue system by designing, realising and testing it. The task has an emphasis on the testing and recording of results for an analogue system to meet their test specification.

Task 3

Task 3 is intended to introduce learners to software control techniques using flowcharts. Several manufacturers produce PIC development systems which can be used to deliver this part of the component. The work must not be limited to 'onscreen' design and emulation, but must involve the actual programing of a PIC chip, and its testing remotely on a physical circuit. Initial program testing can be carried out using a development board to prove the program before final testing on a physical circuit.

Physical circuit

Construction of all systems may be on prototype board, strip board or printed circuit board. Whichever method of construction is chosen, the layout and mounting of components and wiring should be neat and logical, assist the design, allow testing of and fault finding of the system. Pre-constructed circuit boards such as PIC or Arduino development boards are **not** acceptable as the final circuit.

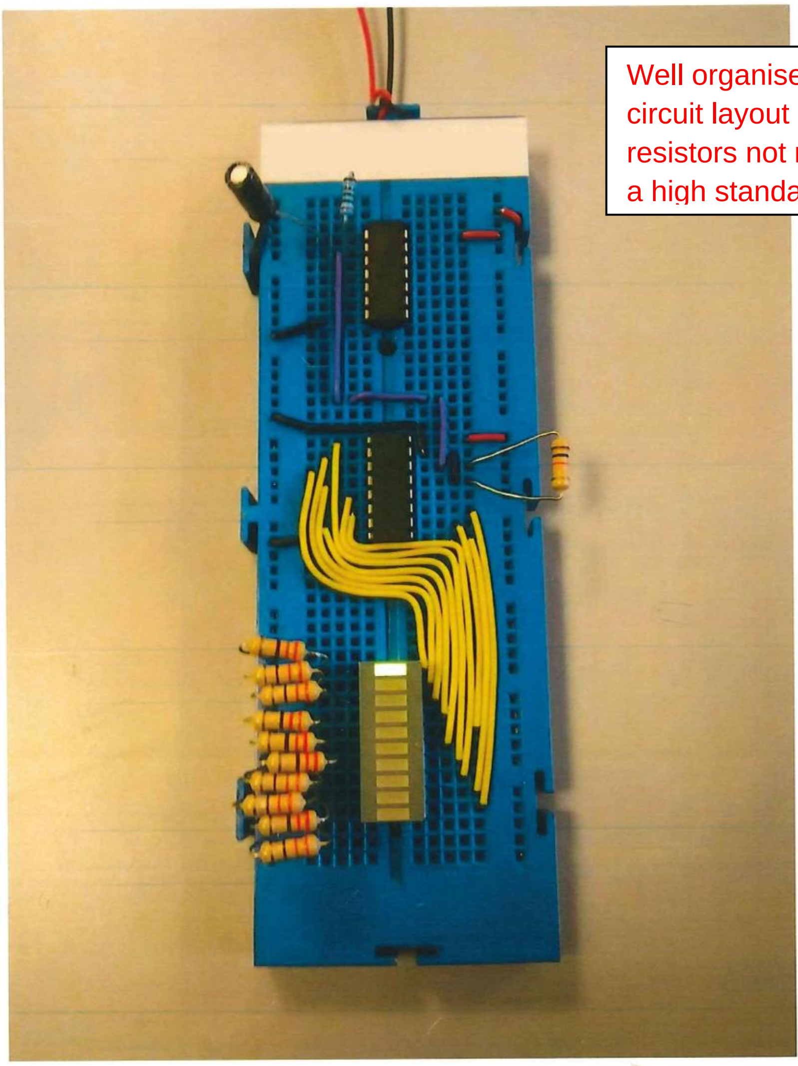
Task 1: Digital system

Bar Graph Scrolling LEDs

Introduction:

Limited analysis of problem and a partial specification.

This circuit is a linear scrolling set of LEDs, as is used ubiquitously in decorative lighting applications (e.g. christmas lights). It cycles progressively through the LEDs, at a constant speed, returning to the first LED after it gets to the last. The LEDs should complete one cycle every second, so each of the ten LEDs should stay on for exactly 0.1S. The circuit will run on 5V±0.1V.

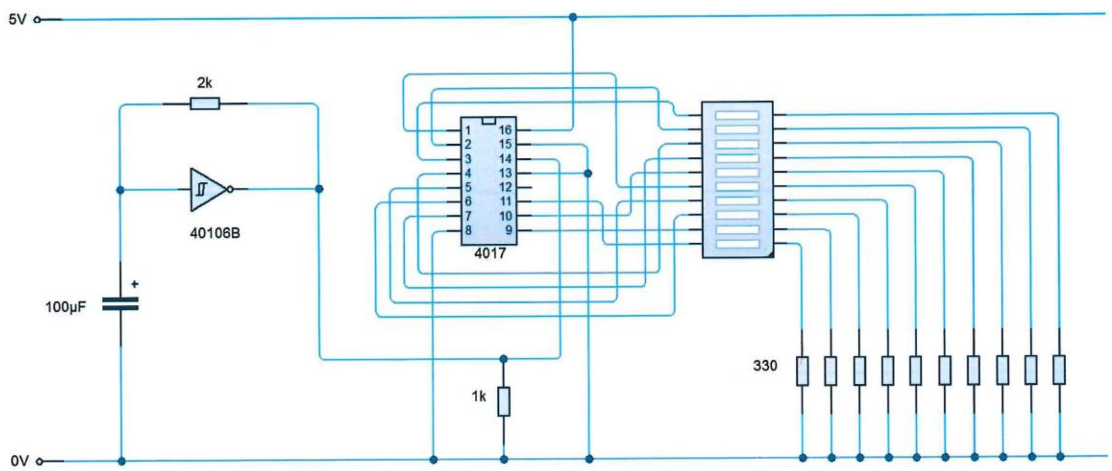


Well organised physical circuit layout but some resistors not mounted to a high standard.

Method of Operation:

The oscillator is based around the 401016 Schmitt-Trigger inverter. The oscillator works by charging and discharging a capacitor through a resistor. The inverter detects when the capacitor has charged/discharged above/below a certain level, and switches it's output on/off accordingly. The time the capacitor takes to transition between the two switching levels dictates the frequency of the output pulses.
The oscillator continuously pulses the clock input of the 4017. The 4017 counts up to 10, displaying the output in a sequential, denary display. When the 4017 gets to 10, the next clock pulse prompts it to reset itself, returning it to 1. The output therefore appears to continuously cycle downwards, then back to the beginning, and so on. The cathodes of all the LEDs are connected to ground by 330Ω resisors, to limit current, and prevent damage, according to $R = \frac{V}{I}$, where V_{LED}=3, and I_{LED}=10mA, so R=300Ω. 330Ω was therefore chosen as the next highest E24 value.
I wanted the LEDs to complete one cycle per second, so, using $T = 0.5RC$, I chose values of 2kΩ and 100µF. This gives a time period of 0.1S, which, for 10 LEDs, means one cycle every 1.0S.

Circuit:



Excellent circuit diagram but no block diagram provided.

Some comparison with specification provided.

I used a digital camera programmed to take one picture every 0.1S, over the course of 1 second. The resulting ten photographs show that the LEDs do in fact complete one full cycle per second:

Time of frame after start of sequence / S	0.1S	0.2S	0.3S	0.4S	0.5S	0.6S	0.7S	0.8S	0.9S	1.0S
Photo of which LED is on.										

I measured the voltage across the LEDs in the bargraph display, which almost all gave a reading of 2.12V(±0.01V). This means, according to $I = \frac{V}{R}$;

$I = \frac{5-2.12}{330} = 0.00873 = 8.73mA$

The LEDs are therefore slightly underdriven, which is safer for the lifetime of each LED, but slightly dimmer than intended.

An oscilloscope trace could have been provided to check accuracy of astable frequency.

The intended brightness of the LEDs could have been considered in the analysis and specification.

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Task 1: Digital system

1. System planning		Mark awarded
3 marks	**The candidate has provided**: • a clear analysis of a problem leading to a design specification in both qualitative and quantitative terms (typically at least 3 of each), and including 3 or more detailed realistic electronic parameters	x x
2 marks	**The candidate has provided**: • some analysis of a problem with a design specification in both qualitative and quantitative terms (typically at least 2 of each), and including 1 or more realistic electronic parameters	x ? ✓
1 mark	**The candidate has provided:** • a limited analysis of a problem and a partial design specification in either qualitative or quantitative terms (typically at least 4 in total)	✓ **1 mark**
0 marks	Response not creditworthy or not attempted.	

2. System Development		Mark awarded
6 - 8 marks	**The candidate has:** • provided a clearly labelled block diagram for the system and developed the system as a series of sub-systems and made predictions regarding its behaviour • produced an accurate good quality fully labelled circuit diagram for the system • planned and produced a very well organised physical circuit layout with all wires arranged vertically/horizontally, and showed good awareness of risk assessment • arranged wires with no unnecessary crossing of components which were mounted to a high standard and showed good awareness of safe working procedures	x ✓ ✓ ?
3 - 5 marks	**The candidate has:** • provided a labelled block diagram for the system and made some attempt to develop the system as a series of sub-systems • produced an accurate well labelled circuit diagram for the system • planned and produced a generally well organised physical circuit layout with most wires arranged vertically/horizontally and showed some awareness of risk assessment • arranged most wires without unnecessary crossing of components which were mounted to a good standard and showed awareness of safe working procedures	x x ✓ ✓ ✓ ✓
1 - 2 marks	**The candidate has:** • made a superficial attempt to develop the system as a series of sub-systems • produced a circuit diagram for the system which was partially labelled or lacked clarity • produced a physical circuit layout with minimal evidence of organisation/planning and showed some superficial awareness of risk assessment/ safe working procedures	✓ ✓ ✓
0 marks	Response not creditworthy or not attempted.	**5 marks**

3. System Realisation		Mark awarded
5 - 6 marks	**The candidate has:** • performed functional tests on all the sub-systems and recorded all relevant results • tested the complete physical system prototype and provided a detailed analysis of the results using standard scientific convention which included most of the relevant electrical measurements • produced an electronic system that worked consistently and reliably and included a comprehensive user guide	x ✓ ✓ x
3 - 4 marks	**The candidate has:** • performed functional tests on most of the sub-systems and recorded most relevant results • tested the complete physical system prototype and provided some analysis of the results using standard scientific convention which included some of the relevant electrical measurements • produced an electronic system that worked most of the time and included a user guide	✓ ✓ ✓ ✓ x
1 - 2 marks	**The candidate has:** • performed functional tests on 1 or more different sub-systems and made some attempt at recording the results • tested the complete physical system prototype and provided a limited analysis of the results • produced an electronic system in which at least 2 sub-systems worked most of the time	✓ ✓ ✓ **4 marks**
0 marks	Response not creditworthy or not attempted.	

4. Evaluation		Mark awarded
3 marks	**The candidate has:** • undertaken a critical and objective evaluation of the performance of the complete system which was valid, made comprehensive comparisons with the design specification and made at least 2 suggestions for improvement with explanations of how they improve the system	x
2 marks	**The candidate has:** • undertaken an objective evaluation of the performance of the complete system which was valid, made some comparisons with the design specification and made at least 2 suggestions for improvement	✓ x
1 mark	**The candidate has:** • undertaken a simple evaluation of the performance of the complete system which was valid in few respects, made minimal comparison with the design specification and made at least 1 superficial suggestion for improvement	✓ x **1 mark**
0 marks	Response not creditworthy or not attempted.	

Task 1 – Total mark

11
20

AS System design and realisation tasks

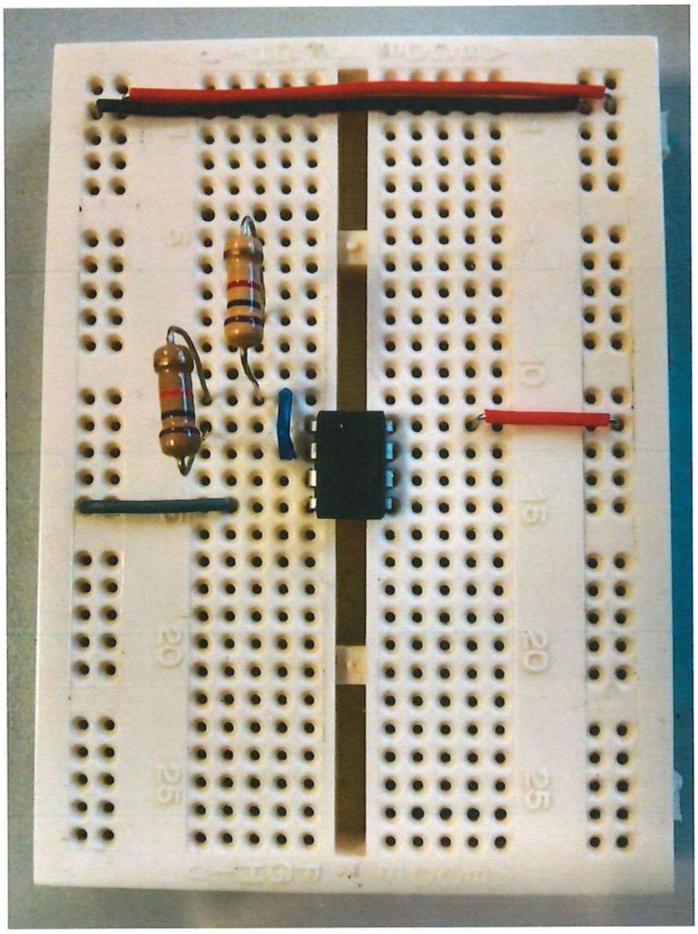
Task 2: Analogue system

Inverting Amplifier

Introduction:

The circuit I built is an inverting amplifier. It takes a given signal at it's input, and produces an output proportional to the inverse of the input signal, multiplied by the gain of the amplifier.
It should accept input signals up to 1V in amplitude, given the supply rail of ±15V(±0.1V), and the gain of -10. It can be used to amplify a small signal, such as in audio equipment.

Minimal analysis but 2 measurable parameters provided.



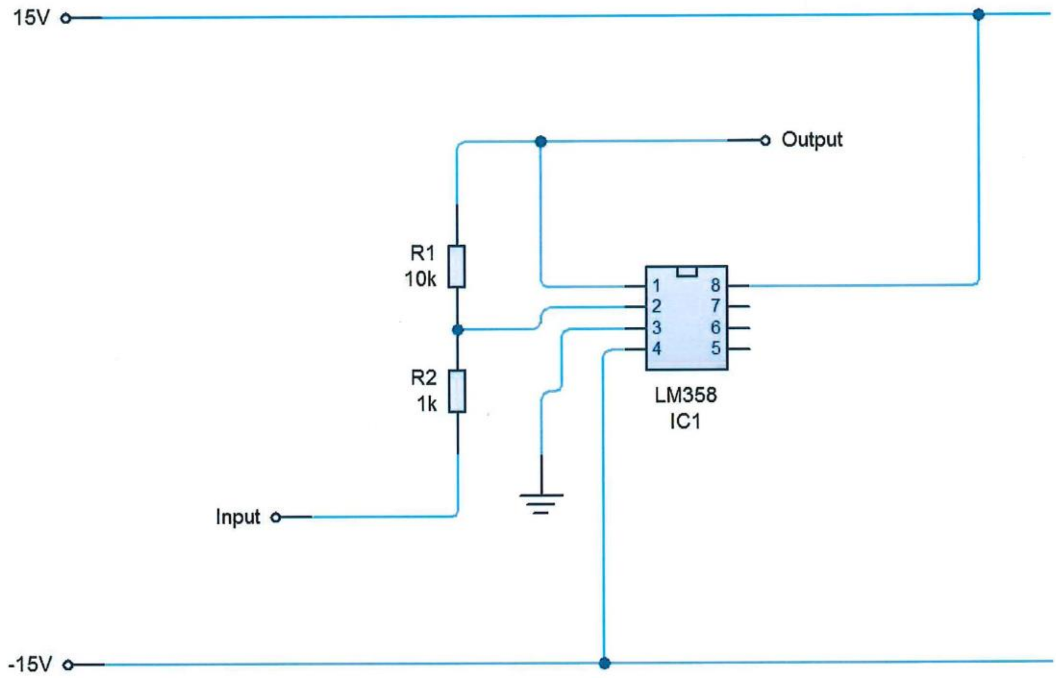
Very well organised physical circuit with all wires arranged vertically/horizontally.

Method of Operation:

The circuit uses an op-amp in a closed-loop gain configuration, with a potential divider combination to set the closed-loop gain of the amp. I decided, for simplicity, to choose resistor values which would give me a gain of -10, according to $G = -\frac{Rf}{Rin}$. I therefore chose a value of 1K for R_{in}, and 10K for R_f.

The gain could then be tested by providing a certain input signal amplitude, and using an oscilloscope to view the amplitude of the output. The output signal should be 10 times the amplitude of the input signal, but in antiphase.

Circuit:



Circuit diagram should contain the symbol for an op-amp rather than a pin out diagram.

Predictions:

I can test the operation of the amplifier by using two oscilloscope probes. One at the input, and the other at the output. The oscilloscope would display two waveforms, in antiphase, the output being ten times the amplitude of the input. For a gain of (-)10, according to $G = -\frac{Rf}{Rin}$:

V_{input} / V	Predicted Outputs / V
0.1	1
0.2	2
0.3	3
0.4	4
0.5	5
0.6	6
0.7	7
0.8	8
0.9	9
1.0	10

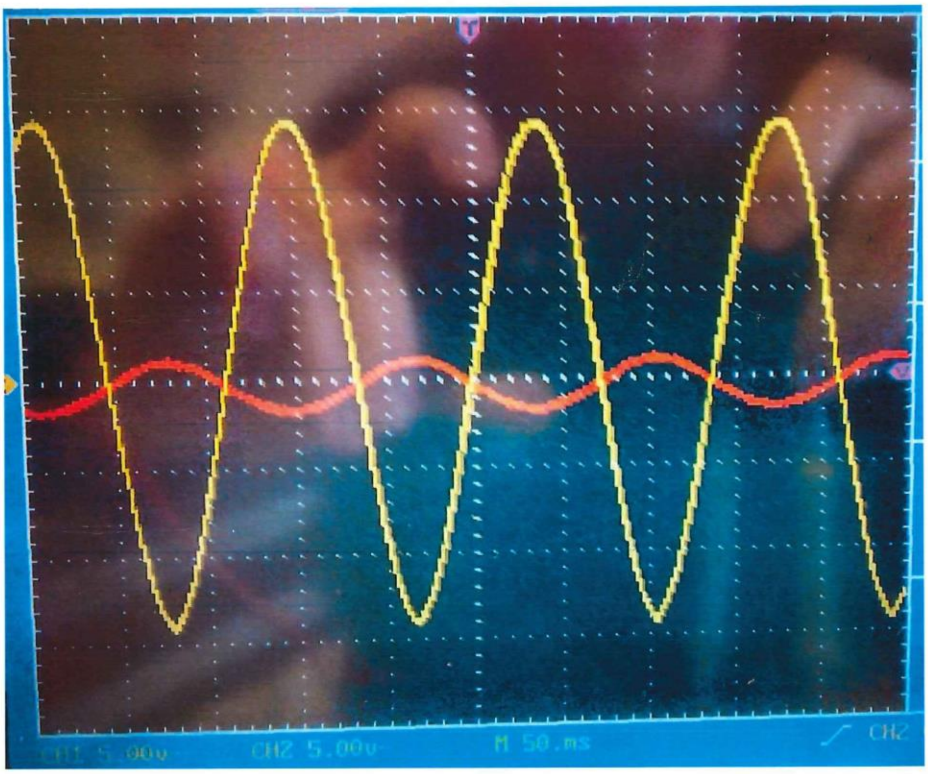
Evidence of planning test procedures but - sign missing in the predicted output voltages.

Testing:

I used an oscilloscope with probes at the inputs and the outputs; I connected the input probe to channel 1 and the output probe to channel 2. On the oscilloscope, I set the two channels to overlay on the display, and the timebase and V/div for both to be the same; 50ms/div and 5V/div respectively. This allowed me to clearly see and illustrate the comparison between the two signal traces.

Identified all the appropriate test equipment.

I used a signal generator to provide a constant frequency signal, of variable amplitude, to the input of the circuit. The oscilloscope traces' intersection with the axes showed the peak amplitude of the two signals. I varied the amplitude of the input signal from 0.1V up to 1.0V in increments of 0.1V. I read-off the value of the amplitude of the wave, displayed on the oscilloscope, and collected them in a table.



The above image shows an oscilloscope with the Input in red, and the Output in yellow. The output amplitude is 14V, showing the output just before clipping occurs. The gain of -10 and the power supply of ±15V implies that the maximum input amplitude should be 1.5V. This is not the case however, due to an approximately 1V voltage-drop across the transistors at either side of the op-amp's output stage. The voltage drop at either side of the output stage therefore limits the output amplitude to ±14V, before saturation, and therefore clipping of an input signal, occurs.

Clearly recorded results in table form/oscilloscope traces but not graphically. Good analysis of the results provided and some justification for the accuracy of most of the measurements made.

Results:

V_{input} / V [±0.1V]	Predicted Outputs / V	V_{output} / V [±0.1V]
0.1	1	1.0
0.2	2	2.0
0.3	3	3.0
0.4	4	4.0
0.5	5	5.0
0.6	6	6.0
0.7	7	7.0
0.8	8	8.0
0.9	9	9.0
1.0	10	10

As shown in the table, the measured outputs are congruous with the predictions of the outputs based on input signal amplitude and gain.
The circuit can therefore be said to work correctly, given that the results are within the ±1V error tolerance of the apparatus.

The evaluation of the performance of system is valid in most respects. Some comparisons with the design specification made.

Task 2: Analogue system

1. System planning		Mark awarded
3 marks	**The candidate has provided**: • a clear analysis of a problem leading to a design specification in both qualitative and quantitative terms (typically at least 3 of each), and including 3 or more detailed realistic electronic parameters	x x
2 marks	**The candidate has provided**: • some analysis of a problem with a design specification in both qualitative and quantitative terms (typically at least 2 of each), and including 1 or more realistic electronic parameters	✓ ✓
1 mark	**The candidate has provided:** • a limited analysis of a problem and a partial design specification in either qualitative or quantitative terms (typically at least 4 in total)	✓ **2 marks**
0 marks	Response not creditworthy or not attempted.	
2. System Development		Mark awarded
4 marks	**The candidate has:** • produced an accurate good quality circuit diagram for the system which was clearly labelled • planned and produced a very well organised physical circuit layout with all wires arranged vertically/horizontally, and showed good awareness of risk assessment	x x ✓ ✓
2 - 3 marks	**The candidate has:** • produced an accurate well labelled circuit diagram for the system • planned and produced a generally well organised physical circuit layout with most wires arranged vertically/horizontally and showed some awareness of risk assessment	x ✓
1 mark	**The candidate has:** • produced a circuit diagram for the system that was partially labelled or lacked clarity • produced a physical circuit layout with minimal evidence of organisation/planning and showed some superficial awareness of risk assessment/ safe working procedures	✓ ✓ **3 marks**
0 marks	Response not creditworthy or not attempted.	

3. System Realisation		Mark awarded
8 - 10 marks	**The candidate has:** • provided comprehensive evidence of planning test procedures and has clearly identified all the appropriate test equipment and made predictions regarding test ranges required • tested the complete physical system prototype with all the relevant numerical measurements of the system parameters being made making, appropriate use of standard scientific convention • provided a detailed justification for the accuracy of most of the measurements made and clearly recorded the results in table form and graphically • provided a detailed analysis of the results	x ✓ x ? ✓
4 - 7 marks	**The candidate has:** • provided evidence of planning test procedures and has identified all the appropriate test equipment • tested the complete physical system prototype with most of the relevant numerical measurements of the system parameters being made, making some appropriate use of standard scientific convention • provided some justification for the accuracy of most of the measurements made and recorded the results in table form and graphically • provided good analysis of the results	✓ ✓ ✓ ✓ ✓
1 - 3 marks	**The candidate has:** • provided minimal evidence of planning test procedures and has identified some appropriate test equipment • partially tested the complete physical system prototype and made basic numerical measurements • recorded results in table form or graphically • provided some analysis of the results	✓ ✓ ✓ ✓ **7 marks**
0 marks	Response not creditworthy or not attempted.	

4. Evaluation		Mark awarded
3 marks	**The candidate has:** • undertaken a critical and objective evaluation of the performance of the complete system which was valid, made comprehensive comparisons with the design specification and made at least 2 suggested improvements in procedures for data collection	x x
2 marks	**The candidate has:** • undertaken an objective evaluation of the performance of the complete system which was valid and made at least 2 comparisons with the design specification	✓ ✓
1 mark	**The candidate has:** • undertaken a simple evaluation of the performance of the complete system which was valid in few respects, made minimal comparison with the design specification and made at least 1 superficial suggestion for improvement	✓ **2 marks**
0 marks	Response not creditworthy or not attempted.	

Task 1 – Total mark	
	14
	20

AS System design and realisation tasks

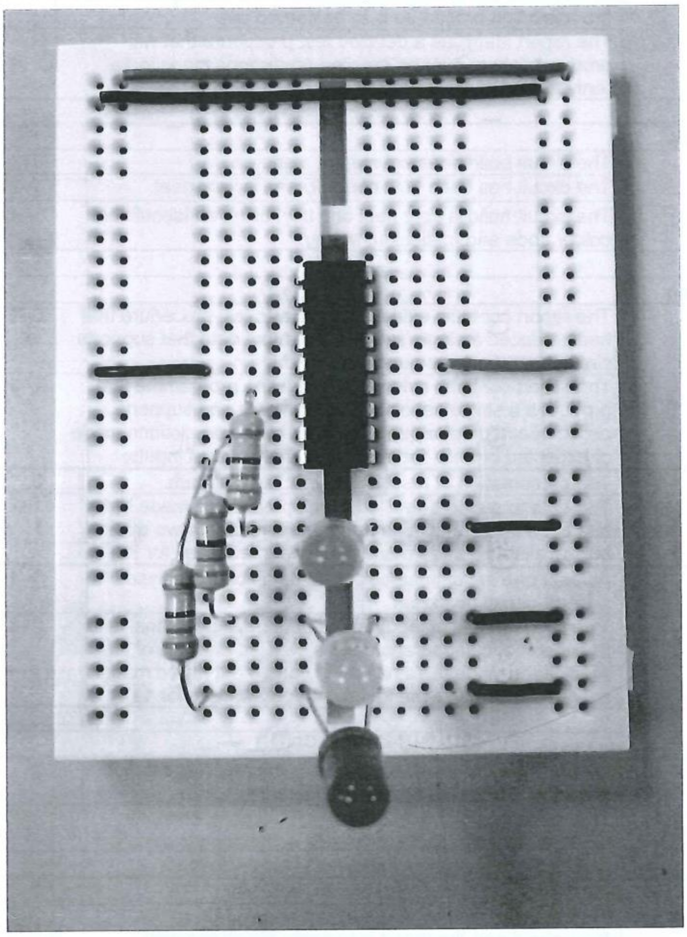
Task 3: Microcontroller system (Flowchart program)

Traffic Light LEDs

A very basic design specification. One measurable parameter provided but little evidence of analysis of the problem.

Introduction:

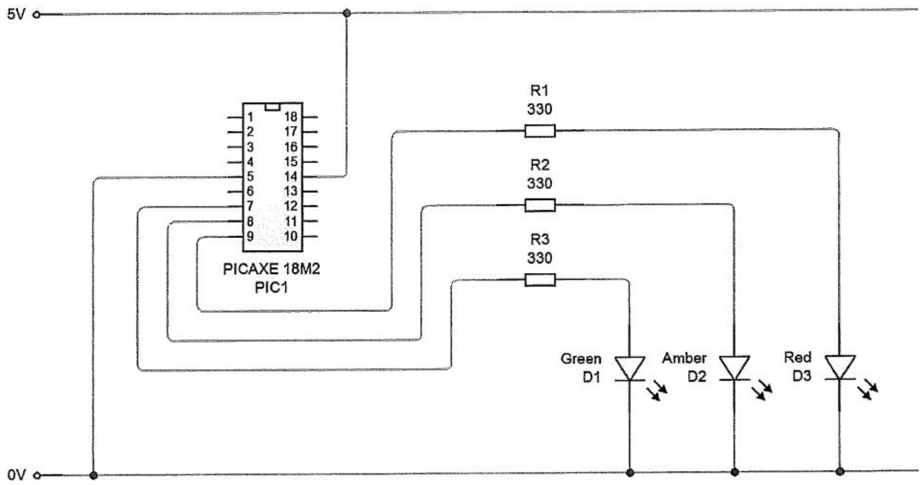
The circuit is a set of traffic lights, which alternate in a timed sequence, used to control the flow of traffic on a road or at a junction. The red and green lights should stay on for 5 seconds each (±0.05S), and the transition time with amber between the two should last for 1 second (±0.01S). It should run on 5V±0.1V.

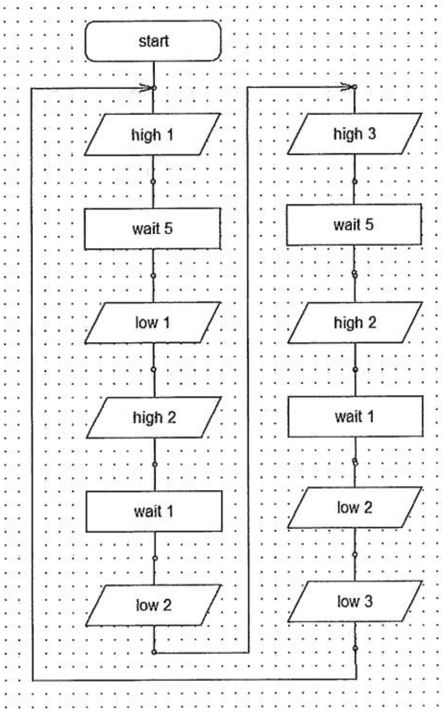


Well organised physical layout. The mounting of the 3 resistors was not to a high standard.

A good accurate fully labelled circuit diagram but no component list provided.

Circuit:





Flowchart solution for a very basic specification with 4 different commands and 3 ports used.

Method of Operation:

When the PIC is first powered on starts running the first command. It will run the sequence illustrated above of red, amber, and green LED's repeatedly. When the last instruction has been executed, it will go back to the first instruction, and cycle through the command lines again.

This loop is achieved via the naming of the primary routine 'main', and, at the end of the routine, performing a call to the routine 'main', thereby endlessly cycling through that routine.

The use of programmable timing periods provides the flexibility to use the PIC in various different contexts, where one might want to change timings to adjust for traffic flow, pedestrian concentrations, etc.

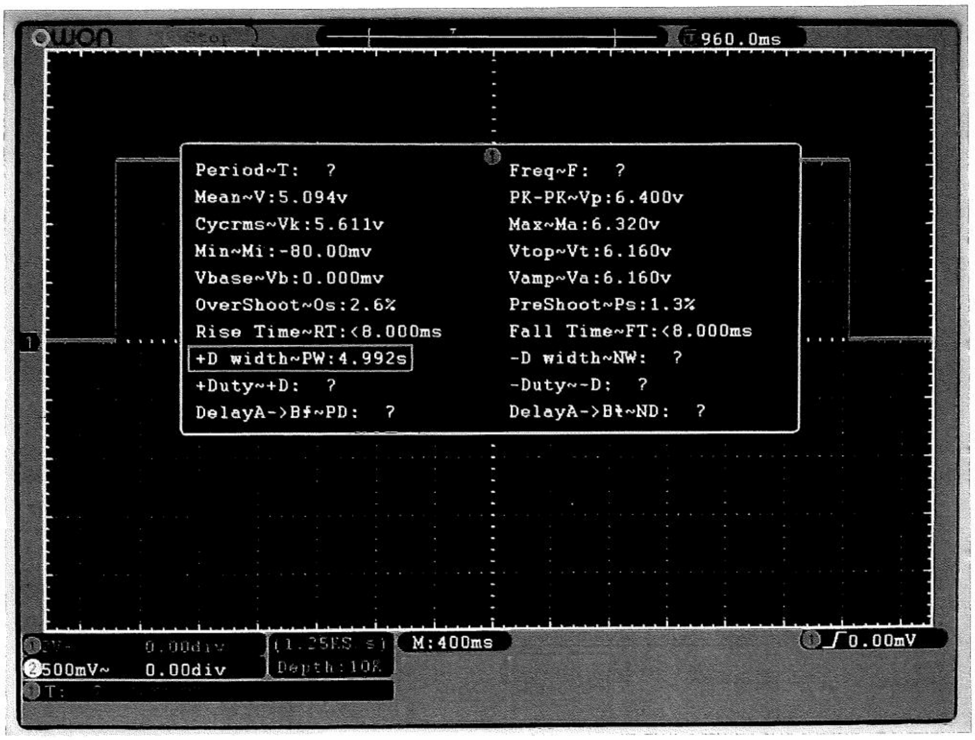
No evidence of computer simulation tests/tests on a development board.

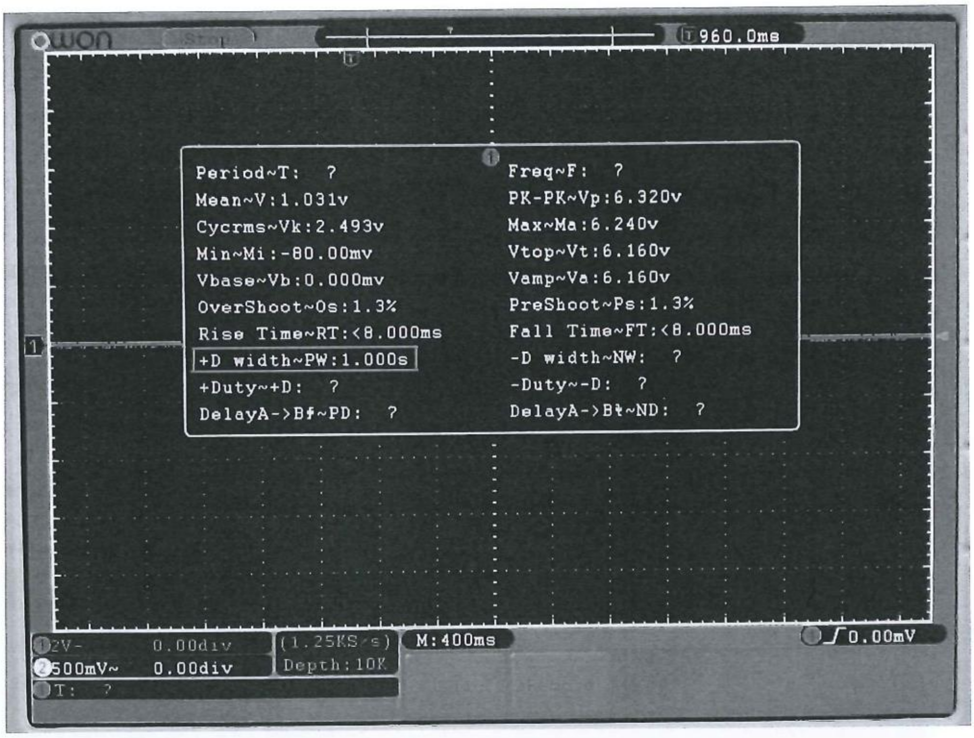
Testing:

I decided to use an oscilloscope to measure the time period of the outputs, as I knew that a stop-clock with 0.01s accuracy was unlikely to be precise enough, given the clock rate of the PICAXE chip, and the instructions-per-cycle rate. The oscilloscope was therefore the only piece of test apparatus capable of measuring the time period accurately enough to detect possible variations from the programmed value.

The oscilloscope was set-up to trigger a timer on the rising edge of the signal, and to stop the timer on the falling edge. The value of the timer duration is displayed as *+D width~PW:* , outlined in green in the photographs.

The images below show the oscilloscope's measurements of the time period of the outputs of pin 1 and pin 2 respectively.





Results:

Results:	Programmed Value / S	Measured Value / S	Percentage error:
Pin 1	5	4.992	0.16 %
Pin 2	1	1.000	0.00%
Pin 3	5	4.997	0.06%

The percentage error between the programmed values and the values measured by the oscilloscope was , at most, 0.16%, for a value of 5s. My intended accuracy was ±1% per second. The lowest measured accuracy was 0.032% per second.

Good testing of the program timings.

The measured accuracy is therefore approximately three times the intended accuracy, concluding the successful operation of the circuit.

Colour	Predicted Outputs / V	V_{output} / V [±0.1V]
Red	1.7	1.72
Amber	2.0	1.93
Green	2.1	2.11

Incomplete evaluation which was valid in some respects with no evidence of suggestions for improvement.

Task 3: Microcontroller system (Flowchart program)

1. System planning		Mark awarded
2 marks	**The candidate has provided**: • a clear and concise analysis of a problem and a design specification in both qualitative and quantitative terms (typically at least 3 of each), and including two or more detailed realistic measurable parameters	x
1 mark	**The candidate has provided:** • An analysis of a problem and a partial design specification in either qualitative or quantitative terms (typically at least 4 in total)	✓
0 marks	Response not credit worthy or not attempted	**1 mark**
2. System Development		Mark awarded
6 - 8 marks	**The candidate has:** • produced a comprehensive flowchart solution to the problem and make predictions regarding its behaviour • devised a program that reacted to and used information from inputs to control outputs and utilised 4 or more port bits • used 8 or more different commands in the program including two types of decision command • produced simulation tests and given a full account of the tests on the proposed flowchart program	x x x ✓
3 - 5 marks	**The candidate has:** • produced a good flowchart solution to the problem • devised a program that reacted to and used information from inputs to control outputs and utilised 3 or more port bits • used 6 or more different commands in the program including one or more types of decision command • produced simulation tests and given a reasonable account of the tests on the proposed flowchart program with minor omissions in the results	? ✓ x x ✓
1 - 2 marks	**The candidate has:** • produced a basic flowchart solution to the problem • devised a program that utilised 2 or more port bits • used 4 or more different commands in the program • produced simulation tests and given a superficial account of the tests on the proposed flowchart program, with some omissions in the results	✓ ✓ ✓ ✓
0 marks	Response not creditworthy or not attempted	**3 marks**

3. System Realisation		Mark awarded
6 - 8 marks	**The candidate has:** • produced an accurate circuit diagram and physical circuit layout which were very well organised and provide a component list • made most wire connections and mounted most components to a high standard and showed good awareness of risk assessment/safe working procedures • downloaded the program to the microcontroller circuit and comprehensively tested the complete physical system prototype; • provided a detailed analysis of the results for a system that worked consistently and reliably	✓ x ? ✓ ✓ ✓ ✓
3 - 5 marks	**The candidate has:** • produced an accurate circuit diagram and physical circuit layout which were organised • made most wire connections and mounted most components to a good standard and showed some awareness of risk assessment/safe working procedures • downloaded the program to the microcontroller circuit and tested the majority of the complete physical system prototype • provided some relevant analysis of the results with some detail for a system that mainly worked	✓ ✓ ✓ ✓
1 - 2 marks	**The candidate has:** • produced a circuit diagram and physical circuit layout which tended not to be very well organised • downloaded the program to the microcontroller circuit and partially tested the complete physical system prototype • provided some superficial analysis of the results for a system that worked at some time.	✓ ✓ ✓
0 marks	Response not creditworthy or not attempted	7 marks

4. Evaluation		Mark awarded
2 marks	**The candidate has:** • undertaken an objective evaluation of the performance of the complete system which was valid, made comprehensive comparisons with the design specification and made at least 2 suggestions for improvement with explanations of how they improve the system	x x x
1 mark	**The candidate has:** • undertaken a simple evaluation of the performance of the complete system which was valid in few respects, made minimal comparison with the design specification and made at least 1 superficial suggestion for improvement	✓ ✓ x
0 marks	Response not creditworthy or not attempted	1 mark

Task 1 – Total mark	12
	20

Acknowledgements

This guide includes work created by students using the following software:

- New Wave Concepts – Circuit Wizard
- Sumdog Ltd – Yenka
- Revolution Education Ltd – PICAXE Editor

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