APPENDIX A

Equations in Electronics

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

$V = IR$	definition of resistance
$P = VI = I^2R = \dfrac{V^2}{R}$	power relationships
$R = R_1 + R_2 + \ldots$	resistors in series
$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$	resistors in parallel
$R = \dfrac{R_1 R_2}{R_1 + R_2}$	two resistors in parallel
$V_{OUT} = \dfrac{R_2}{R_1 + R_2} V_{IN}$	potential divider
$E = Pt$	energy transfer
$A.1=A,\ A.0=0,\ A.A=A,\ A.\overline{A}=0$ $A+1=1,\ A+0=A,\ A+A=A,\ A+\overline{A}=1$	Boolean identities
$\overline{A+B} = \overline{A}.\overline{B}$	de Morgan's theorem
$\overline{A.B} = \overline{A}+\overline{B}$	de Morgan's theorem

In addition, learners should be able to select correctly from a list and apply the following relationships:

$C = \dfrac{Q}{V}$	capacitance
$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$	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
$A + \overline{A}\,.\,B = A + B$	
$A\,.\,B + A = A\,.\,(B + 1) = A$	Boolean identities
$G = \dfrac{V_{OUT}}{V_{IN}}$	amplifier voltage gain
$G = 1 + \dfrac{R_F}{R_1}$	non-inverting op-amp circuit voltage gain
$G = -\dfrac{R_F}{R_{IN}}$	inverting op-amp circuit voltage gain
$\text{slew rate} = \dfrac{\Delta V_{OUT}}{\Delta t}$	definition of slew rate
$\text{slew rate} = 2\pi f V_P$	minimum slew rate for distortion of free sinusoidal signal
$V_{OUT} = -R_F\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + ...\right)$	summing amplifier output voltage
$V_{OUT} = V_S \text{ for } V_+ > V_-$	comparator output voltage
$V_{OUT} = -V_S \text{ for } V_+ < V_-$	
$V_{OUT} = V_{IN}$	voltage follower circuit
$T = RC$	time constant
$V_C = V_0\left(1 - e^{-\frac{t}{RC}}\right)$	charging capacitor
$t = -RC\ln\left(1 - \dfrac{V_C}{V_0}\right)$	charging capacitor
$V_C = V_0 e^{-\frac{t}{RC}}$	discharging capacitor
$t = -RC\ln\left(\dfrac{V_C}{V_0}\right)$	discharging capacitor

$V_{rms} = \frac{V_0}{\sqrt{2}}$; $I_{rms} = \frac{I_0}{\sqrt{2}}$ rms values

$I_C = h_{FE} I_B$	bipolar transistor
$I_D = g_M (V_{GS} - 3)$	MOSFET
$P = I_D^2 r_{DSon}$	power dissipated in a MOSFET
$f = \frac{1}{T}$	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
$f \approx \frac{1}{RC}$	Schmitt astable circuit
$V_r = \frac{I}{f_r C}$	ripple voltage
$X_C = \frac{1}{2\pi f C}$	capacitive reactance
$X_L = 2\pi f L$	inductive reactance
$Z = \sqrt{R^2 + X^2}$	impedance of a series circuit
$f_b = \frac{1}{2\pi R C}$	break frequencies for *RC* filters
$V_{OUT} \approx V_{IN} - 0.7$	for an emitter follower
$V_{OUT} \approx V_{IN} - 3$	for a source follower
$V_{OUT} = V_{DIFF} \left(\frac{R_F}{R_1} \right)$	difference amplifier

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$ resonant frequency for *LC* filters

$R_D = \dfrac{L}{r_L C}$	dynamic resistance
$N_{CH} = \dfrac{\text{available bandwidth}}{\text{channel bandwidth}}$	capacity of transmission media
$\text{maximum data rate} = 2 \times \text{available bandwidth}$	data rate
$G_{dB} = 10 \log_{10} \dfrac{P_{OUT}}{P_{IN}}$	gain in decibels
$SNR_{dB} = 10 \log_{10} \dfrac{P_S}{P_N} = 20 \log_{10} \dfrac{V_S}{V_N}$	signal to noise ratio
$Q = \dfrac{f_0}{\text{bandwidth}} = \dfrac{2\pi f_0 L}{r_L}$	*Q*-factor
$m = \dfrac{(V_{max} - V_{min})}{(V_{max} + V_{min})} \times 100\%$	depth of modulation
$\beta = \dfrac{\Delta f_c}{f_i}$	modulation index
$\text{Bandwidth} = 2(\Delta f_0 + f_i) = 2(1+\beta) f_i$	transmitted FM bandwidth
$c = f\lambda$	wave speed
$V_L \approx V_Z \left(1 + \dfrac{R_F}{R_1}\right)$	stabilised power supply
$\phi = \tan^{-1}\left(\dfrac{R}{X_C}\right)$	triac phase control
$\text{resolution} = \dfrac{\text{i/p voltage range}}{2^n}$	ADC/PCM resolution
$P_{MAX} = \dfrac{V_S^2}{8R_L}$	power amplifier

APPENDIX B

Mathematical requirements and exemplification

In order to be able to develop their skills, knowledge and understanding in electronics, learners need to have been taught, and to have acquired competence in the following areas of mathematics indicated in the table below.

The table illustrates where these mathematical skills may be developed and could be assessed. The list of examples is not exhaustive. These skills could be developed in other areas of the specification content.

	Mathematical skill	Exemplification of mathematical skill (assessment is not limited to the examples given below)
E.0 – arithmetic and numerical computation		
E.0.1	Recognise and make use of appropriate units in calculations	Convert between units with different prefixes, e.g. A to mA Identify the correct units for physical properties such as Hz, the unit for frequency
E.0.2	Recognise and use expressions in decimal and standard form	Use frequencies expressed in standard form such as 2.5×10^7 Hz
E.0.3	Use fractions, ratios and percentages	Calculate the fraction of the charge lost from a capacitor in a given time
E.0.4	Estimate results	Estimate the resistor values needed in a potential divider so that the output voltage does not drop significantly
E.0.5	Use calculators to handle power functions, exponential and logarithm functions	Calculate the power rating required for a resistor Calculate the time constant from a decay curve
E.0.6	Use calculators to handle tan and $\tan^{-1}$ functions	Calculate the phase angle for a triac phase-control circuit
E.1 – handling data		
E.1.1	Use an appropriate number of significant figures	Report calculations to an appropriate number of significant figures Understand that calculated results can only be reported to the limits of the least accurate measurement
E.1.2	Find arithmetic means	Calculate a mean value for repeated experimental findings
E.1.3	Make order of magnitude calculations	Evaluate equations with variables expressed in different orders of magnitude, e.g. 150 kΩ and 2.6 mA
E.1.4	Use Karnaugh maps	Simplify a logic system
	Mathematical skill	**Exemplification of mathematical skill (assessment is not limited to the examples given below)**
E.2 – algebra		
E.2.1	Understand and use the symbols: =, <, <<, >, >>, $\propto$, $\approx$, Δ	Recognise the significance of the symbols in the expression: $\text{slew rate} = \frac{\Delta V_{OUT}}{\Delta t}$
E.2.2	Change the subject of an equation, including non-linear equations	Rearrange $P = \frac{V^2}{R}$ to make R the subject

E.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Calculate the frequency of a 555 astable by substituting the values for R_1, R_2 and C into the equation: $f = \frac{1.44}{(R_1 + 2R_2)C}$
E.2.4	Solve algebraic equations	Find a capacitor value for a given time delay and resistance in a 555 monostable
E.2.5	Use Boolean algebra	Simplify a logic system
E.3 – graphs		
E.3.1	Translate information between graphical, numerical and algebraic forms	Measure the ripple voltage from output graphs for rectified power supplies
E.3.2	Plot two variables from experimental or other data	Plot I-V characteristics of a diode
E.3.3	Determine the slope of a graph	Calculate a resistance value from a V-I graph
E.3.4	Calculate the rate of change from a graph showing a linear relationship	Calculate the slew rate from a V-t graph
E.3.5	Draw and use the slope of a tangent to a curve as a measure of rate of change	Calculate the gain of an amplifier from the transfer characteristic
E.3.6	Sketch relationships which are modelled by $y = \sin x$ and $y = \sin^2 x$	Sketch a graph of power against time for an alternating current in a resistor
E.3.7	Use log-log and semi-log graph grids	Sketch and interpret gain curves for filters