Using A Scientific Calculator in the RSGB Full Radio Amateurs Exam (Version 3)

George Smart, M1GEO — http://www.george-smart.co.uk/

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This booklet was written to help better explain the mathematics involved in the full amateur radio licence examination. It was written to accompany the RSGB's Advance! Full Amateur Radio Examination book. It aims to elaborate the on the formulae in the RSGB book, and show how to use them. The booklet guides you through key presses and examples within each section. This book only covers the mathematics for the exam; the other topics will need to be learned/revised from elsewhere.
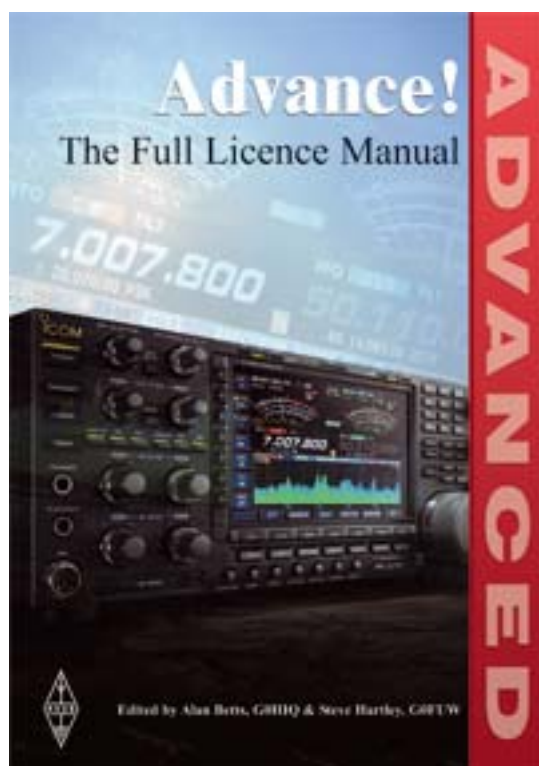
With that, lets get on with the show...

Contents

Chapter 1

Metric Scales

The metric or SI prefix is a unit prefix that precedes a basic unit of measure to indicate a decadic multiple or fraction of the unit. Common examples in amateur radio include mega, as in mega-Hertz; kilo, as in kilo-Ohms; nano, as in nano-Farad. The key prefixes are shown in the table below:

Prefix	Symbol	10^x
giga	G	9
mega	M	6
kilo	K	3
-	-	0
milli	m	-3
micro	μ	-6
nano	n	-9
pico	p	-12

You will notice that engineers and scientists tend to use numbers with exponents (10^x) that are multiples of 3. Other values do exist (for example, centimetres, which is 10^{-2}) but these are not commonly used in engineering (engineers favour millimetres). There is no real short cut way to learn these. You've just got to know them, and if you know them well, you're much less likely to make silly mistakes during the exam. Commit these to memory, so that they're second nature to you.

Chapter 2

Scientific Calculator

This booklet was written for a Casio $fx - 83$ natural display scientific calculator. This is the standard educational calculator used in the UK, used from secondary school through university. It's also the recommended calculator for the Radio Amateur's exams. Take a while to familiarise yourself with the calculator and locate all of the key features as there are slight variations in the range, all with small differences. This booklet should hopefully work for all variations of the $fx - 83$ as well as covering many other calculators offering similar functionality. This guide was tested on a Casio $fx - 83GT+$:
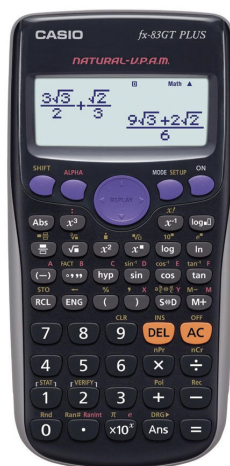
2.1   Setting the Calculator Mode

The first important step is to get the calculator into the correct mode. The combination does depend on you; if you're confident enough with the use of a calculator, then feel free to configure the calculator as you wish. My suggestions are to use *LineIO*, *Degrees*, and a *Normal* number display. Also make sure that *Statistics* mode is disabled. When correctly configured, the top line of the calculator should show a capital 'M' and a 'D'. If you see anything else, consult the manual to disable the feature.

To enter the set up mode, power on the calculator and press the $^{\text{SHIFT}}$ key momentarily, followed by the $^{\text{MODE SETUP}}$ key. You should be presented with the set up menu on the LCD. First press the number corresponding to *LineIO*, on my device this is 2. The calculator will return to it's normal screen. Again enter the set up menu, and this time press the number corresponding to *Degrees* or *Deg*; for me, 3. Finally, re-enter the set up menu and select *Normal* or *Norm*, using the 1 key. Here you're asked to select a type of normal. Press 1. You should be ready to go!

2.2   Entering Metric Scaled Values

This is one of the tricky parts of using the calculator, if you're not used to it. It takes a bit of practice, and combines the metric (SI) prefixes from above. Let's say you want to enter a resistance of 1.6 kilo-Ohms. In Ohms, that's $1,600\Omega$. That's not so bad. Now how about entering 91 pico-Farads? That's 0.000000000091 Farads. The number of zeros quickly becomes unwieldy. It is for this reason that we use what is called *scientific notation* or *standard form*. This takes various forms, but typically mathematicians, scientists and engineers use the metric prefix that you see above. This lets you easily

enter the value of 91 pF (pico-Farads). Looking up the metric prefix for pico, we see that it has the *exponent* -12. This means that pico is a scaling of $\times 10^{-12}$ or in other words, if we multiply 91 by 10^{-12}, we will get 91 pF. This gives us the form 91×10^{-12} Farads.

Let's go back to our 1.6 kilo-Ohms example from before. Kilo has the exponent 3. If we multiply 1.6 by 10^3 we will get our 1.6 kilo-Ohms: 1.6×10^3 Ohms.

Here are a few examples:

- 10 nano-Henry (nH) = 10×10^{-9}

- 145 mega-Hertz (MHz) = 145×10^6

- 16 micro-Farad (μF) = 16×10^{-6}

- 17.46 milli Joules (mJ) = 17.46×10^{-3}

It is important to be comfortable with this idea, as it's used a lot in Electronics. Some values, such as Farads (units of capacitance) and Henrys (units of inductance) are too big for every day use and much smaller values are used. You need to be able to enter these carefully into the calculator. Here's how:

On the calculator, you will see an *exponent* button ($\times 10^x$). It may also say 'Exp' on older models. This is the button you use for entering these powers in. 91 pF, as we know, is 91×10^{-12} Farads. This is entered as follows: Key in 91. Then press the exponent button, $\times 10^x$, then key in -12. That's it. Let's look at the other examples from above:

- 1.6 kilo-Ohms (kΩ) = 1.6×10^3

  - 1.6 $\times 10^x$ 3

- 10 nano-Henry (nH) = 10×10^{-9}

  - 10 $\times 10^x$ -9

- 145 mega-Hertz (MHz) = 145×10^6

  - 145 $\times 10^x$ 6

- 16 micro-Farad (μF) = 16×10^{-6}

  - 16 $\times 10^x$ -6

- 17.46 milli Amperes (mA) = 17.46×10^{-3}

  - 17.46 $\times 10^x$ -3

And that's it. You just treat this number exactly as you would if you had entered a single digit number.

2.3 Reading Metric Scaled Values

This section initially seems very silly. Of course you can read, but there are a few tips and features that the calculator will do for you, that can save you time and silly mistakes. Firstly, the calculator will, where possible, put very big or very small answers into scientific notation. Although this won't tell you pico, nano, Mega or Giga, as you would like, it will tell you 10^{-12}, 10^{-9}, 10^6 or 10^9 and you should be able to translate that. If you press the equals key (=) after entering any of the numbers above, you will notice that the calculator will show you the same number... BUT... it may have moved the decimal point in an attempt to get what's called *standard form*. As an example, entering 91 pF as 91×10^{-12} from above and pressing equals (=) shows me 9.1×10^{-11}, and as you can see the calculator has moved from 91 to 9.1 and the exponent has moved from -12 to -11. You don't need to worry why. Just know that if you press the Engineering button (ᴱᴺᴳ), it will return it to the closest multiple of 3, and so I get 91×10^{-12} once again. If you keep pressing ᴱᴺᴳ you will move higher and higher up the multiples of 3, because 1 nano-Farad is 1000 pico-Farad and so on. You can go backwards, or to lower multiples of 3 by pressing the shift key (ˢᴴᴵᶠᵀ) followed by the engineering key (ᴱᴺᴳ).

Another thing you may notice is that the calculator often *factorises* the results, or shows them as fractions. It's not uncommon to see answers like

$$\frac{1}{3}\pi$$

being displayed on the calculator screen. To convert this into a decimal number, use the scientific↔decimal ($^{S⇔D}$) key. The display should then change to show you the decimal number, in this case $\boxed{0.1061032954}$.

One final thing here is to say that the answer key (^{Ans}) can be used as a variable to take the result from the previous calculation and perform a new task with it. Here's an example. Calculate 5×8 on the calculator and you get the result 40. Then supposing you want to take this value (40) and divide it by 7? No problem: Press the ^{Ans} key which will display $\boxed{Ans}$ on the screen (this is substituted with your previous answer when the calculator works). Next press the divide key ($\div$) and then finally, the 7 key, followed by equals ($=$). You should either see $\boxed{\frac{40}{7}}$ (in which case, press $^{S⇔D}$) or $\boxed{5.714285714}$. Good.

I have known people use these calculators for a long time and not known about the ^{ENG} or $^{S⇔D}$ buttons. They are very useful.

Chapter 3

RMS

Root-Mean-Squared or RMS is a key concept when referring to AC voltages and currents. Let us first define some parameters of a sine wave:
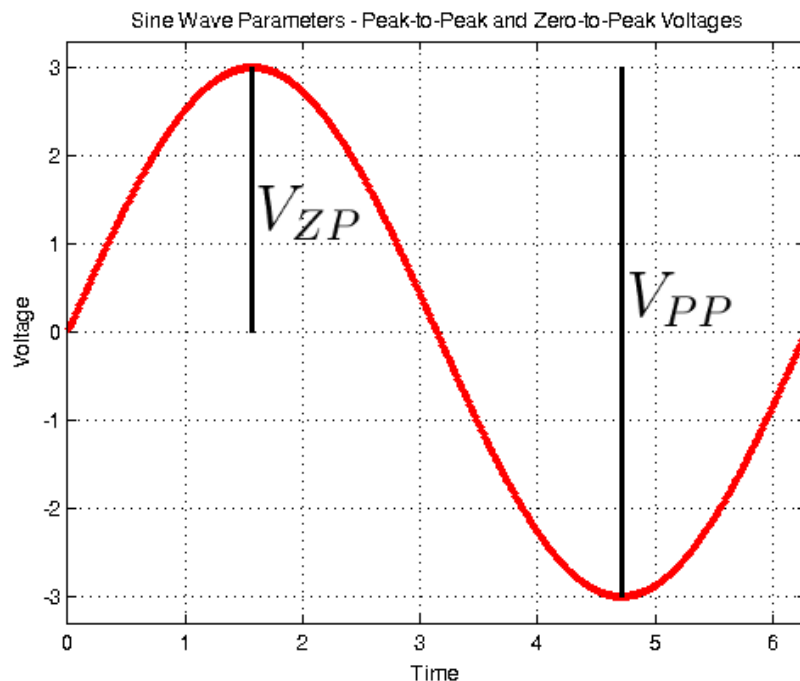

The above sine wave is an AC voltage because throughout the cycle (one complete up and down) the voltage is both positive and negative. Most of the time, an AC voltage will be centred at 0 Volts, as it is here, but this doesn't have to be the case. Two parameters are marked on the above graph, V_{ZP} and V_{PP}. V_{ZP} refers to the voltage between zero and the peak (the highest or lowest voltage in one cycle) and V_{PP} refers to the voltage between the two peaks (from the lowest voltage to the highest).

In the above example, we can see that the lowest voltage is -3 Volts and the highest Voltage is +3 Volts. From the 0 Volts line to either peak is 3 Volts, thus giving $V_{ZP} = 3$ Volts, while from the highest point to the lowest point is from -3 to +3, giving $V_{PP} = 6$ Volts.

You will need to be careful with the notation because it is regularly changed; you often also see V_P or V_{PK} for the zero-to-peak voltage and V_{PP} or V_{P-P} for the peak-to-peak voltage. Also be careful when the sine wave isn't centred on 0 Volts – use the centre of the sine wave, half way between the two peak voltages as a 'virtual zero' and add any DC offset to the numbers afterwards.
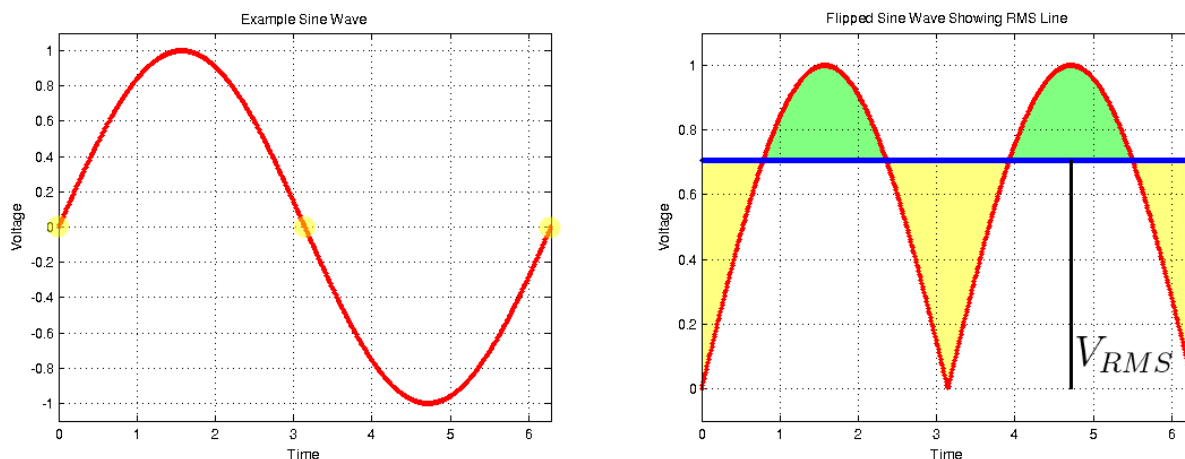
Looking at the sine wave on the left graph above, there are two points where there the voltage is zero: where the trace crosses the x-axis, highlighted with yellow circles. Yes, you are right, there are 3 yellow dots, but the first and last dots are really the same dot when the next cycle is introduced. At these points, no energy transferred. A DC voltage, by comparison, is a flat line in time, and so energy is always transferred. The idea of RMS is to find the equivalent continuous DC voltage that the varying AC voltage provides.

Energy is transferred regardless of the polarisation (direction of voltage) or direction of current. We can consider this as flipping the negative half of the sine wave up, as in the red trace of right graph above.

By way of qualitative explanation, if we take the pale green sections of the above-right graph and cut them up, they will exactly fill the pale yellow sections. The dividing line where the areas in pale green exactly equal the areas in pale yellow is the RMS voltage, shown here by a blue line.

This all sounds a little complicated, but it ensures comparable power between AC and DC systems. This is very commonly used for comparing power, such as with a radio transmitter which has DC input power producing an AC voltage at the output in the form of RF.

Mathematically, all the above discussion comes down to these two equations.

$$V_{ZP} = \frac{V_{PP}}{2} \qquad V_{RMS} = \frac{V_{ZP}}{\sqrt{2}}$$

The left equation says that the zero-to-peak voltage is half the peak-to-peak voltage. The right equation tells you where the RMS voltage is, or referring to the above-right graph, where the blue 'cut line' is.

You often see the reciprocal of the square root of 2 ($\frac{1}{\sqrt{2}}$) evaluated to something like 0.707. Then you can just multiply the zero-to-peak voltage with 0.707 to obtain the RMS voltage – this trick can speed things up, but only when you're used to it – it can also cost you if you're not!

$$V_{RMS} = V_{ZP} \times 0.707$$

If you're given a peak-to-peak (V_{PP}) value, you first need to convert that to a zero-to-peak (V_{ZP}) value first. On the calculator, you divide the peak-to-peak voltage by 2 to find the zero-to-peak voltage:

- V_{PP} ÷ 2 =

This gives you V_{ZP} which you can now use to find V_{RMS}:

- V_{ZP} ÷ √ 2 =

For example, given a voltage of 756 Volts peak-to-peak, we can calculate the RMS voltage with the two steps above

- 756 ÷ 2 = ⟨378⟩ Volts zero-to-peak.

- 378 ÷ √ 2 = ⟨267.286⟩ Volts RMS.

Finally, note that this only applies to sine waves. Other types of wave, such as square or triangle, have different RMS values with explanations outside the scope of this guide. One useful one to remember is the RMS of a square wave is half the zero-to-peak voltage as the top boxes would fill the bottom boxes gaps.

Chapter 4

Ohms Law and Power

Ohm's law states that if a current I goes through a wire with resistance R, there will be a voltage drop of V Volts potential difference over the length.

$$V = I \times R$$

To enter this into the calculator:

- Key in the value of I, being careful to take note of the scaling units, Amps, milli Amps, etc. Use the metric prefixes as described above if needed.

- Then press the multiplication key, $\times$.

- Then enter the value of resistance, again, noting any scaling units such as kilo-Ohms.

- Press the equals key, $=$, to get the answer.

Example:
   Given a heater resistance of 12.5Ω, with a current of 29 Amperes flowing, we can work out the potential difference across the heater

- 29 $\times$ 12.5 $=$ $\boxed{\frac{725}{2}}$ or $\boxed{362.5}$ Volts.

This equation can be reworked into: $I = \frac{V}{R}$ or $R = \frac{V}{I}$. The process for evaluating these is very similar:

- Key in the value of V.

- Then press the divide key, $\div$.

- Then enter the value of either resistance (R) or current (I), depending on which formula you are using.

- Press the equals key, $=$, to get the answer. If you are shown a fraction, then simply press the scientific↔decimal ($S{\leftrightarrow}D$) key to get a decimal number.

Example:
   A 81Ω is connected across a bench power supply set to 13.8 Volts. How much current will flow through the resistor?

- 13.8 $\div$ 81 $=$ $\boxed{\frac{23}{135}}$ or approximately $\boxed{0.1703}$ Amps, which is $\boxed{170.3}$ mA.

Though not strictly Ohms Law, the power law can also be grouped in here. This law states a component is dissipating power P if it has a current I flowing through it with a potential difference of V volts across it.

$$P = I \times V$$

This is the same method as Ohm's Law. It's current I times ($\times$) voltage V, which gives power P .

- Enter the current using metric prefixes where appropriate.

- Then press the multiplication key, $\times$, and enter the voltage.

- Press the equals key, $=$. You should get your answer. Power has the unit of Watts (W).

Example:

Given a mains heater running from 230 Volts AC RMS, drawing a current of 8.7 Amps, we can calculate the power of the heater:

- 8.7 $\times$ 230 $=$ $\boxed{2001}$ Watts. Remember that this is approximately 2 kW.

This again can be rearranged, by substituting some of the Ohms law formulas, to give the following: $P = \frac{V^2}{R}$ or $P = I^2 \times R$. These formula are a little more complicated because they have a squared (^{2}) term as in I^2, for example. This means $I \times I$. You'll notice the calculator has a *squared* button: x^2 . Here's how it's used for $P = \frac{V^2}{R}$:

- Firstly key in the voltage V. Then press x^2 . You should see a little 2 (^{2}) to the top right of the number you entered. This is the squared.

- Next, press the divide key, $\div$.

- Then enter the value of resistance and press equals, $=$. Press the scientific$\leftrightarrow$decimal ($S \Leftrightarrow D$) key to get a decimal if needed.

Example:

Given a battery of 9 Volts, and a resistor of 301Ω, the power dissipated in the resistor is:

- 9 x^2 $\div$ 301 $=$ $\boxed{\frac{81}{301}}$ or $\boxed{0.2691}$ Watts, which is approximately $\boxed{270}$ mW.

For $P = I^2 \times R$ we swap the divide $\div$ for multiplication $\times$.

- Firstly key in the current I. Then press x^2 . Again you get a little 2 (^{2}) to the top right of the number.

- Next, press the multiplication $\times$ key.

- Then enter the value of resistance and press equals, $=$.

Example:

If we have a 3 Amps AC RMS going through a 4Ω loudspeaker coil, what is the power dissipated?

- 3 x^2 $\times$ 4 $=$ $\boxed{36}$ Watts.

Chapter 5

Potential Dividers

The image below is of a resistive voltage divider. A voltage of V_{in} is put across two resistors, R_1 and R_2, to ground. The output, from ground to V_{out}, is a fraction of the input. The key is to work out the current flowing from V_{in} to ground through R_1 and R_2. Then, using Ohms law, we can work out the voltage at the output, V_{out}, which is the same as the voltage across $R2$.
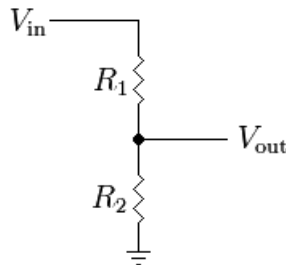
The derivation is out of the scope of this guide, but is explained in the book. The derivation is unimportant for the Full Radio Amateur's exam, as you are given the following formula on the formula sheet. What matters is that given two values for R_1 and R_2 you and V_{in}, you can calculate V_{out}.

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$

Here's how:

- Enter the value of R_1 and add it to R_2. This gives us $R_1 + R_2$. Press equals $=$.

- Now we need to put $R_1 + R_2$ at the bottom. For this we use the reciprocal button, which looks like this: $x^{\text{-1}}$.

    - We recall our answer to $R_1 + R_2$ with the Ans key, and put it on the bottom of the fraction with the $x^{\text{-1}}$ key. Press equals $=$.

- Now we take our answer again with the Ans key, and multiply $\times$ by the value of R_2. Press equals $=$.

- Finally multiply $\times$ by V_{in} and press equals $=$ for the final answer.

Example Keystrokes:

Given that V_{in} is 13.8 Volts, R_1 is 470Ω and R_2 is 330Ω, what is the voltage at V_{out}?

- 470 $+$ 330 $=$ $\boxed{800}$

- Ans $x^{\text{-1}}$ $=$ $\boxed{\frac{1}{800}}$ or $\boxed{1.25 \times 10^{-3}}$

- Ans $\times$ 330 $=$ $\boxed{\frac{33}{80}}$ or $\boxed{0.4125}$

- Ans $\times$ 13.8 $=$ $\boxed{\frac{2277}{400}}$ or $\boxed{5.6925}$

So the answer, V_{out} is 5.6925 Volts.

Chapter 6

Parallel Plate Capacitors

Two metal plates facing each other constitute a capacitor. Consider the diagram below. Two metal places, both with area A square metres, facing each other separated by distance d has a capacitance of C Farads. The dielectric (separating) material is also important. The book doesn't make too much mention of the dielectric material. The book refers to the dielectric constant of K.
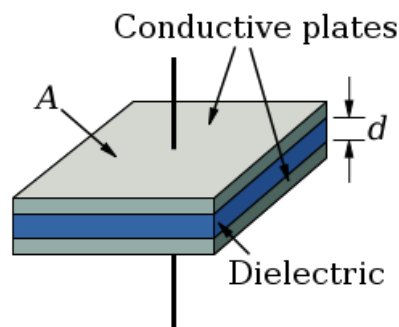
Using the formula below, you can work out the capacitance for a given place size of area A separated by a dielectric of parameter K and distance d.

$$C = \frac{K \times A}{d}$$

To evaluate this:

- Enter d then $\boxed{x^{-1}}$ to put d on the bottom. Press $\boxed{=}$.

- $\boxed{Ans}$ $\boxed{\times}$ K $\boxed{\times}$ A $\boxed{=}$ to get the answer.

Capacitance is also expressed as a charge (in Coulombs) divided by a voltage.

$$C = \frac{q}{V}$$

- q $\boxed{\div}$ V $\boxed{=}$ to get C.

The previous formula is usually expressed as
$$q = C \times V$$

- C $\boxed{\times}$ V $\boxed{=}$ will give q. Remember that C is very small, and so metric prefixes will need to be used.

The book gives no examples of this so none are included here.

Chapter 7

Reactance & Impedance

Passive components perform basic functions in circuits. Resistors dissipate energy as heat and can be used to limit the current in a circuit. Inductors store energy in a magnetic field. Capacitors store energy in an electric field. Inductors and capacitors can been seen as complimentary components. They have the opposite effect to each other. Inductors block high frequencies but allow low frequencies. Capacitors allow high frequencies but block low frequencies. This is because of their reactance, which is discussed in each of the subsections below. Reactance is the non-resistive component of impedance in an AC circuit; this, too, is discussed in a subsection below.

7.1 Resistors

The resistance of a resistor is not effected by frequency, it therefore has a reactance of 0 Ohms

$$X_R = 0$$

The only metric that the resistor has is it's resistance, R_R.

7.2 Inductors

An ideal inductor has only reactance, X_L, which depends on the value of inductance, L, and the frequency at which the device is used, f. If we know these two values, we can calculate the reactance, X_L. To an AC signal at a frequency of f Hz, the inductor looks as a resistor of X_L Ohms, with a phase shift (discussed later).

$$X_L = 2\pi f L$$

You should also note that the resistance, R_L, of an ideal inductor is 0. In practise you will notice some resistance from the wire.

$$R_L = 0$$

You can calculate the reactance of the inductor as below:

- 2 ✖ ᔕᴴᴵᶠᵀ ×10ˣ ✖ f ✖ L

- Notice that the ᔕᴴᴵᶠᵀ ×10ˣ combination gives you Pi, π, on the Casio $fx - 83$ series. This may not be the same on every calculator, so do check.

Example:

Power chokes are large inductors designed to remove AC noise from DC power lines. They are ideal for removing alternator whine on mobile radios installed in cars. Can we see how it works? Let's look: What is the reactance, X_L, of a 100 mH choke at 200 Hz?

- 2 ✖ ᔕᴴᴵᶠᵀ ×10ˣ ✖ 200 ✖ 100×10^{-3} ═ $\boxed{40\pi}$ or $\boxed{125.7}$ Ohms.

This reactance of 125.7 Ohms will remove much of the 200 Hz ripple on the car's power supply. The battery and alternator in the vehicle will have an extremely low resistance, in the order of a few milli Ohms. Your radio receiver will also have a low impedance power input. If you consider the circuit as a potential divider, then you notice that all of the signal is lost inside the 125.7Ω of the power choke. Very little AC signal propagates through the power choke. To the DC power going through the choke, there is no effect.

7.3 Capacitors

The ideal capacitor also only has a reactance, X_C, which depends on the capacitance value, C, and the frequency f as with the inductor. We can also calculate the value of the capacitor's reactance, X_C, using the formula below. Notice it's the reciprocal of the inductor's formula.

$$X_C = \frac{1}{2\pi f C}$$

The ideal capacitor should have in infinite resistance, R_C. However, this is not always the case in practice and the capacitor may have a very large resistance due to it's internal make up and the dielectric used.

$$R_C = +\infty$$

To Calculate the reactance, X_C, of the capacitor we use the same $^{\text{SHIFT}}$ $\times 10^x$ combination to get π, and the reciprocal button x^{-1} to put the expression on the bottom of the fraction as follows:

- 2 $\times$ $^{\text{SHIFT}}$ $\times 10^x$ $\times$ f $\times$ C $=$

- Ans x^{-1} $=$

Example:

We want to block the DC bias voltage between two stages in an RF power amplifier. This means, that between two components we want the AC signal to pass through easily, but the DC bias to be completely blocked. The amplifier is designed for the 70 centimetres band ($\approx$430 MHz). The designer has chosen a coupling capacitor of value $100pF$. What is the reactance of the capacitor at this frequency? Will this capacitor perform the required job?

- 2 $\times$ $^{\text{SHIFT}}$ $\times 10^x$ $\times$ 430×10^6 $\times$ 100×10^{-12} $=$ $\boxed{0.2701769682}$

- Ans x^{-1} $=$ $\boxed{3.701277746}$ which is approximately 3.7Ω.

Yes, it would be fine. Although the AC signal experiences a reactance of 3.7Ω, the DC bias voltage sees an almost infinite DC resistance of R_C. So the DC voltage will be lost in the very large resistance, but the AC signal will pass through fine.

7.4 Impedance

The antenna impedance of almost all radio equipment is 50Ω resistive. A 50Ω resistor makes a good dummy load.[1] This is because it is purely resistive (remember that the resistor has no reactance).

It is more useful to combine the idea of resistance and reactance together. This is what impedance is:

$$Z = \sqrt{R^2 + X^2}$$

To enter this into a calculator, enter the following:

- Press the *square root* key $\sqrt{\Box}$

- Key in the value of resistance, and then press the squared key, x^2

- Press the addition key, $+$

- Key in the value of reactance, then press the squared key, x^2

- Press equals: $=$

Example:

Supposing an inductor has a reactance of 56Ω and a DC resistance of 4Ω. Using the keystrokes above it is possible to calculate the impedance of the coil:

- $\sqrt{\Box}$ 56 x^2 $+$ 4 x^2 $=$ $\boxed{4\sqrt{197}}$.

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[1]Assuming it's not a wire-wound resistor, which will have an inductance.

- Pressing the scientific↔decimal (**S⇔D**) key will evaluate the decimal: approximately $\boxed{56.14}$ Ohms.

This tells us how what the resultant impedance is. We have no way of telling how reactive or resistive the impedance is, nor can we tell if the reactance is made from capacitance or inductance, so we introduce the concept of phase. Because of the reactance, the current and voltage across the impedance is no longer *in phase*; the maximum current isn't when there is a maximum voltage — this allows for very high voltages and currents in antenna systems and explains why things melt and burn out or spark and arc over inside ATUs. The ATU is an attempt to add inductance and capacitance to the circuit in order to cancel the reactive part of the impedance, leaving the radio with the pure resistance that it likes. A simple mnemonic for remembering the relationship of voltage and current in inductors and capacitors is

<div align="center">

ELI the ICE man

</div>

E symbols electromotive force; voltage to you and me. I symbolises current. The L in ELI refers to the inductor. The C in ICE refers to the capacitor. You notice that the E comes before the I in the ELI (inductor) case, but around the other way, I before E in the ICE (capacitor) case. Note; this is not a formula but a simple phrase to help remember the relationship between current and voltage in inductors and capacitors. It tells you:

- In an inductor, the voltage leads the current.

- In a capacitor, the current leads the voltage.

These phase differences are what cause antenna mismatches and result in SWR in feeders. The discussion behind this is outside the scope of this booklet.

Chapter 8

Combining Passive Components

These components can be connected in various combinations. For the Full Radio Amateurs exam, you need to know how components of the same type combine to give a new value.

8.1 Resistors in Series

Resistors in series simply add up. The current (electrons) have to go through each resistor, so a single electron experiences the resistive affects of all the resistors.
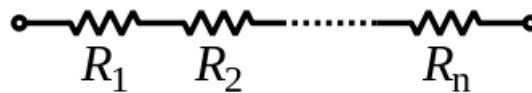
The total resistance, R_T, is given by the formula:

$$R_T = R_1 + R_2 + \ldots + R_n$$

To input this into the calculator is trivial. It is a simple addition. Notice the dots ($\ldots$) and the term R_n? This is just mathematical notation for adding on as many as you need.

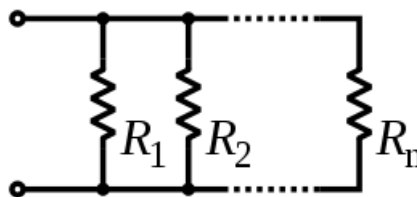- R_1 **+** R_2 **+** $\ldots$ **+** R_n **=**

Example
  Given four resistors, $R_1 = 10\Omega$, $R_2 = 20\Omega$, $R_3 = 30\Omega$ and $R_4 = 40\Omega$ we key in:

- 10 **+** 20 **+** 30 **+** 40 **=** $\boxed{100}$ Ohms total series resistance.

It is important to note that the total resistance R_T must be greater than the largest resistor: 100Ω is larger than 40Ω.

8.2 Resistors in Parallel

Resistors in parallel are a little more complicated. Here, the reciprocals of the resistances add up. Take the resistance of R_1, the reciprocal is $\frac{1}{R_1}$ or R_1^{-1}. In this case, the current (electrons) goes through any one of the resistors, so a single electron experiences only one resistor. For this reason, the total resistance R_T is less than the smallest resistor.

The total resistance, R_T, is given by the formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

Resistors in parallel have a reciprocal relationship. The keystrokes are as follows.

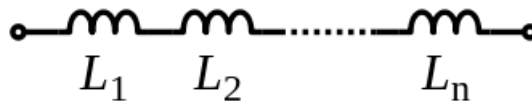- R_1 **x⁻¹** **+** R_2 **x⁻¹** **+** $\ldots$ **+** R_n **x⁻¹** **=**

- **Ans** **x⁻¹** **=**

Example:
Again, given the same four resistors, $R_1 = 10\Omega$, $R_2 = 20\Omega$, $R_3 = 30\Omega$ and $R_4 = 40\Omega$ we key in:

- 10 **x⁻¹** **+** 20 **x⁻¹** **+** 30 **x⁻¹** **+** 40 **x⁻¹** **=**

- **Ans** **x⁻¹** **=** $\boxed{\frac{24}{5}}$ or $\boxed{4.8}$ Ohms.

Notice that this time, R_T is less than the smallest value. 4.8Ω is less than 10Ω.

8.3 Inductors in Series

Inductors in series behave exactly as resistors in series. The inductance adds up in a straightforward manor.

$$L_T = L_1 + L_2 + \ldots + L_n$$

To enter this into the calculator:

- L_1 **+** L_2 **+** $\ldots$ **+** L_n **=**

Example
Given three inductors, $L_1 = 83\mu$H, $L_2 = 77\mu$H, $L_3 = 53\mu$H we key in:

- 83×10^{-6} **+** 77×10^{-6} **+** 53×10^{-6} **=** $\boxed{2.13 \times 10^{-4}}$ Henrys total series inductance. Use the engineering key (**ENG**) to get μH $\boxed{213}$ micro Henrys.

The total inductance L_T would be greater than the largest single inductor: 213μH is larger than 83μH.

8.4 Inductors in Parallel

Again, inductors in parallel follow the same analysis as the resistors in parallel. The reciprocals of the inductances add up:
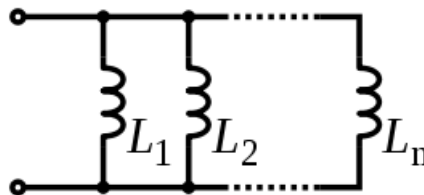
$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_n}$$

The keystrokes are as follows.

- L_1 **x⁻¹** **+** L_2 **x⁻¹** **+** $\ldots$ **+** L_n **x⁻¹** **=**

- **Ans** **x⁻¹** **=**

Example:
   Taking the same three inductors as the series example,$L_1 = 83\mu$H, $L_2 = 77\mu$H, $L_3 = 53\mu$H, we key in:

- 83×10^{-6} **x⁻¹** **+** 77×10^{-6} **x⁻¹** **+** 53×10^{-6} **x⁻¹** **=**

- **Ans** **x⁻¹** **=** $\boxed{2.277741914 \times 10^{-5}}$ Henrys. $\boxed{22.8}$ micro Henry.

The total inductance, L_T, will be less than the smallest single inductor. 22.8μH is less than 53μH.

8.5 Capacitors in Series

Capacitors in series have the reciprocal relationship that resistors and inductors have in their parallel configuration. If we consider the schematic below, we can see that the number of dielectric gaps between the two end points is increased by 1 each time we add a new capacitor. If you refer to *Parallel Plate Capacitors* section above, this can be considered to be changing the distance between the plates, as well as effecting the area if the capacitors are of different values (and constant K (ϵ_0) if the capacitor physics is different [e.g., electrolytic, ceramic disc, mylar]). You just need to know the formula is the same as for parallel resistors.
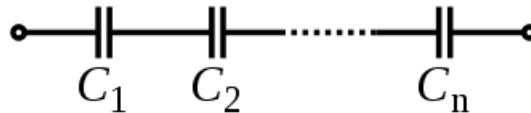
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$$

The keystrokes are as follows.

- C_1 **x⁻¹** **+** C_2 **x⁻¹** **+** $\ldots$ **+** C_n **x⁻¹** **=**

- **Ans** **x⁻¹** **=**

Example:
    $C_1 = 10$nF and $C_2 = 1200$pF

- 10×10^{-9} **x⁻¹** **+** 1200×10^{-12} **x⁻¹** **=**

- **Ans** **x⁻¹** **=** $\boxed{1.071428571 \times 10^{-9}}$ Farads. $\boxed{1.071}$ nano-Farads. ($\boxed{1071}$ pico-Farads).

The value of C_T will be smaller than the smallest single capacitor. This principle is used quite a lot because it can increase the voltage a capacitor will handle as the larger effective plate spacing alters the electric field inside the individual capacitors. 1071pF is less than 1200pF, so we're good.

8.6 Capacitors in Parallel

Capacitors in parallel just add up, as with resistors and inductors in series. Consider this to be just an addition of plate areas.
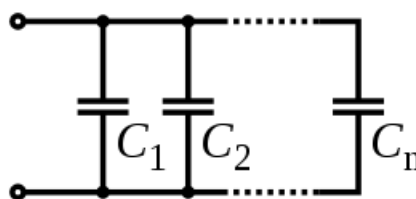
$$C_T = C_1 + C_2 + \ldots + C_n$$

To enter this into the calculator:

- C_1 **+** C_2 **+** $\ldots$ **+** C_n **=**

Example:
    With the same two capacitors as before:$C_1 = 10\text{nF}$ and $C_2 = 1200\text{pF}$

- 10×10^{-9} **+** 1200×10^{-12} **=** $\boxed{1.12 \times 10^{-8}}$ Farads. $\boxed{11.2}$ nano-Farads. ($\boxed{11200}$ pico-Farads).

The total capacitance of the capacitor combination, C_T, must be greater than the largest individual value. This principle is used in power supplies where very large capacitor values are required to smooth the rectified mains. It's common to see 4 or more capacitors in parallel inside a good high current power supply. 11.2nF is larger than our largest capacitor of 10nF.

Chapter 9

Time Constants, Frequency & Wavelength

Time and frequency are reciprocally related. Hertz, the unit of frequency, has the meaning of "per second". A signal at 10 Hz has ten oscillations per second. Frequency is the reciprocal of time, and time the reciprocal of frequency:

$$f = \frac{1}{T}$$

or

$$T = \frac{1}{f}$$

This is simple to enter into the calculator:

- T x^{-1} $=$, or
- f x^{-1} $=$

For example:

If we have a period of $29\mu S$, we can work out the frequency:

- 29×10^{-6} x^{-1} $=$ $\boxed{34482.75862}$ Hertz. Approximately $\boxed{34.5}$ KHz.

You can swap the positions of T and f, too:

Given a frequency of 509 KHz, we can find the period...

- 509×10^3 x^{-1} $=$ $\boxed{1.964636524 \times 10^{-6}}$ Seconds. Approximately $\boxed{1.96}$ micro-Seconds.

Wavelength, λ is also an important parameter. This relates the physical size of the wave to it's frequency, with a scaling of the waves velocity. For most practical purposes, you can assume that light is travelling at the speed of light, c, which it is approximately 3×10^8 metres/second. The speed of the wave is given the symbol, v, for velocity. Wavelength is the speed of light divided by the frequency. Amateur radio bands are typically referred to in terms of wavelength. On some occasions you will see a *velocity factor, VF,* for example when working with coax. This shows the fraction of the speed of light the wave travels in coax: $v = VF \times c$. Unless stated, it's safe to assume the velocity factor is 1.

$$\lambda = \frac{v}{f}$$

or

$$f = \frac{v}{\lambda}$$

To enter this into the calculator, enter:

- v $\div$ f $=$, or
- v $\div$ λ $=$

For example:

If we take the frequency of 14.175 MHz, we can work out the wavelength:

- $3 \times 10^x 8$ $\div$ $14.175 \times 10^x 6$ $=$ $\boxed{\frac{4000}{189}}$ or $\boxed{21.164}$ metres.

Using the other formula, you can convert from wavelength, λ, to frequency, f.

Converting a wavelength of 70 centimetres (0.7 metres) to frequency:

- $3 \times 10^x 8$ $\div$ 0.7 $=$ $\boxed{428571428.6}$ Hz. Which is approximately $\boxed{428.6}$ MHz.

Chapter 10

Resonance

To create a signal on a given frequency, we need some components with an kind of in built sense of timing. Resistors, inductors and capacitors can be used for this purpose. Low frequency applications tend to use RC (resistor-capacitor) or RL (resistor-inductor) circuits keep timing. Higher frequency applications, such as those in radio, almost exclusively use LC (inductor-capacitor) circuits. As mentioned before inductors and capacitors store energy in the forms of magnetic and electric fields, respectively. If we connect an inductor and capacitor together, the stored energy will *bounce* from inductor to capacitor until it is all lost into the inductor's wire resistance and the capacitors leakage. Combine this with some active devices (transistor, FET, valve) and you can get the oscillations to continue indefinitely, creating a signal on the desired frequency.
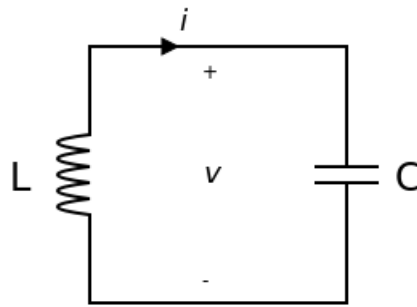
Because we have connected the inductor and capacitor together, we must equate the two reactances, X_L and X_C.

$$X_L = X_C \longrightarrow 2\pi f L = \frac{1}{2\pi f C} \longrightarrow f^2 = \frac{1}{2^2 \pi^2 LC} \longrightarrow f = \frac{1}{2\pi\sqrt{LC}}$$

You should recognise the formula $f = \frac{1}{2\pi\sqrt{LC}}$ as the formula for resonance. The same logic holds for RC and RL circuits, but LC is the most used and most complicated analysis. This is all taught in the book in more detail, so if this is a little hazy, re-read it there. Wikipedia also has a good entry for "LC circuit". So the formula is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

This formula is used to find the resonant frequency of an inductor and capacitor combination, such as that above: To enter it into the calculator:

- L ✕ C =

- √ Ans =

- Ans ✕ 2 ✕ SHIFT ×10ˣ = (notice SHIFT ×10ˣ gives the π symbol).

- Ans x^{-1} =

For example, Given a capacitor of 119pF and an inductor of 365nH, we can calculate the resonant frequency, f, thus:
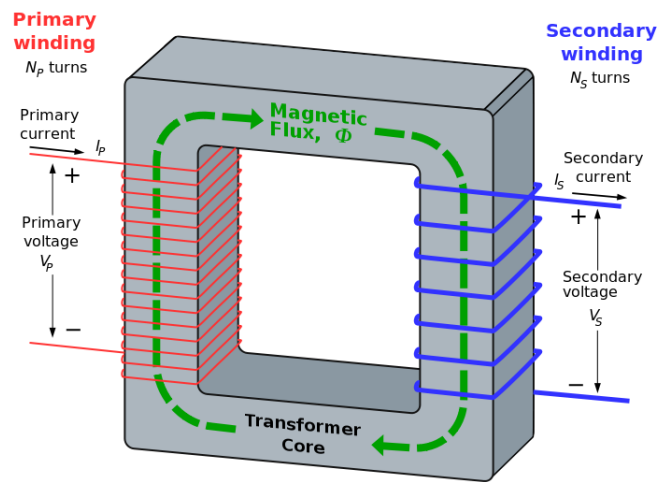
- 365 ×10ˣ -9 ✕ 119×10ˣ -12 =

- √ Ans =

- Ans ✕ 2 ✕ ^{SHIFT} ×10^{*x*} =

- Ans *x*⁻¹ = $\boxed{24149059.34}$ Hz. Approximately $\boxed{24.1}$ MHz.

Chapter 11

Transformers

A transformer is a power converter that transfers electrical energy from one circuit to another through inductively coupled conductors.

We know that the power on both sides of the transformer must be the same (assuming 100% efficency) - i.e. the power we get out (secondary winding) is equal to the power we put in (primary winding). This is a valid approximation for modern transformers, which can be up to 99% effieient. The power in the primary winding, P_P, is, by Ohms Law, equal to the multiplication of the primary winding's voltage, V_P and the primary winding's current, I_P: $P_P = V_P \times I_P$. This is true for the secondary winding parameters P_S, V_S and I_S: $P_S = V_S \times I_S$. We can then write all of the parameters into one formula:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$

We don't really need to know the above formula, but it's included so you can see how these things relate.

The voltages in the primary and secondary windings are scaled by the ratio of turns on the primary winding (N_P) and the secondary winding (N_S):

$$V_S = V_P \times \frac{N_S}{N_P}$$

This relationship holds also for the currents in the transformer - Notice that the numbers of windings, N_P and N_S, are reversed (the fraction is around the other way) to the case of voltage:

$$I_S = I_P \times \frac{N_P}{N_S}$$

If we are considering voltages, we enter

- $N_S \div N_P =$

- Ans $\times$ V_P $=$

If we are considering currents, we enter

- N_P $\div$ N_S $=$

- Ans $\times$ I_P $=$

Notice how for voltage we enter N_S first and for current we enter N_P.

For example, a transformer used in a linear power supply is found to have 1200 turns on the primary winding and 60 turns on the secondary winding. If we apply a primary voltage of 240 Volts AC RMS, we can calculate the secondary winding voltage as follows:

- 60 $\div$ 1200 $=$

- Ans $\times$ 240 $=$ $\boxed{12}$ Volts AC RMS.

Using the same transformer, if the primary winding has a current of 800mA, we can find the secondary current:

- 1200 $\div$ 60 $=$

- Ans $\times$ 800 $\times 10^x$ -3 $=$ $\boxed{16}$ Amps AC RMS.

The impedance, for reasons outside the scope of this document, is related to the squared of the turns ratio:

$$Z_S = Z_P \times \left(\frac{N_S}{N_P} \right)^2$$

This is useful for impedance matching, for example, between modules in a radio receiver:

- N_S $\div$ N_P $=$

- Ans x^2 $=$

- Ans $\times$ Z_P $=$

An example, a valve audio amplifier is matched to a loudspeaker. The primary impedance of the value stage is 1250Ω. The output transformer has 500 turns on the primary winding and 40 turns on the secondary winding. Using the formula above, we can calculate the best speaker impedance; 4Ω, 8Ω or 16Ω.

- 40 $\div$ 500 $=$

- Ans x^2 $=$

- Ans $\times$ 1250 $=$ $\boxed{8}$ Ohms

So, the 8Ω speaker would be best choice.

Chapter 12

Transistors

The RSGB Advance! book does not elaborate much on the theory and operation of transistors. From the intermediate examination, you should recall that the transistor can be used to give amplification of current, either in a very non-linear switching application, such as turning a bulb on and off, or it can be used in the design of linear RF power amplifiers such as those in the output stages of your radio transceiver. The diagram below shows what goes on inside an NPN transistor.
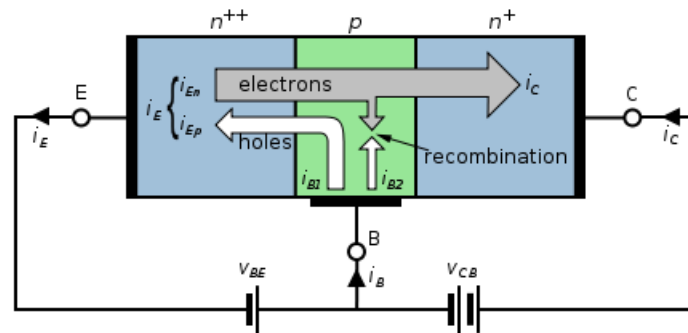
Looking at the way the currents flow through the device, we can say the emitter current (i_E) is equal to the sum of the base current (i_B) and collector current (i_C).

$$i_E = i_B + i_C$$

To calculate the collector emitter current we simply add the base current to the collector current.

- i_B **+** i_C **=**

A quick example; if we take a low gain power transistor, with a collector current of 3 Amps and a base current of 20 milli Amps, we can calculate the current in the emitter:

- 20×10^x-3 **+** 3 **=** ⎡3.012⎤ Amps.

The common-emitter current gain is represented by β. This is the ratio of base current (i_B) to collector current (i_C):

$$\beta = \frac{i_C}{i_B}$$

β varies wildly between devices, even within the same batch. It is very unpredictable and uncontrollable, so it is the designer's job to ensure that the functionality of the circuit doesn't depend on β. Small signal transistors typically have a large current gain, but overall deal with small currents. Power transistors tend to have low current gains, but can deal with high currents — this explains why transistors are used in stages, starting small and working up. To enter this into the calculator:

- i_C **÷** i_B **=**

So taking the values from before, collector current of 3 Amps and a base current of 20 milli Amps, we can calculate the current gain, β.

- 3 **÷** 20×10^x-3 **=** ⎡150⎤ times.

Chapter 13

Decibels

Logarithms seem to confuse people. A lot! They need not to though. The decibel (dB) is a logarithmic unit that indicates the ratio of a physical quantity (typically power) relative to a reference level. As this is a ratio, the reference level is important. Typically, the reference is implied in the units; examples include dBm (dB relative to 1 milli Watt of power in 50Ω), dBW (dB relative to 1 Watt of power into 50Ω), dBd (dB relative to a dipole antenna), and so on. These are all common. The license conditions specify the maximum transmitter power in dBW. Using decibels can greatly simplify calculating the effective radiated power (ERP), because antenna gains can simply be added to transmitter powers, etc. They really are useful, but, can cause real confusion if not correctly understood.

Generally speaking, unless you're using a well known reference, such as those listed above with the addition of a few others, a good rule of thumb is to use the input signal as the reference and the output signal as the measured. If the result is positive the system has gain. If the result is negative, the gain is negative, or the system has a loss (such as an attenuator).

Just to stress again that decibels are a ratio. They express how much bigger the top of the fraction is over the bottom. Also note the formulas are different for power and amplitude.

13.1 Power

This section is for power. For quantities such as voltage and current, see the amplitude section. The definition of decibel is as follows:

$$G_{dB} = 10 \log_{10} \left(\frac{P_{meas}}{P_{ref}} \right)$$

To enter this into the calculator, the following is done:

- P_{meas} ÷ P_{ref} =

- 10 × log Ans =

As an example here, we'll take a direct example from a friend's shack: He uses an Yaesu FT-817 5 Watt transceiver to drive a B.N.O.S 144 MHz Linear Amplifier. With a drive of 5 Watts, the amplifier produces an output of 60 Watts. We can calculate the gain of the amplifier in dB as above:

- 60 ÷ 5 =

- 10 × log Ans = 10.79181246 dB, approximately a gain of 10.8 dB.

13.2 Amplitude

So far we've only looked at decibels with regard to ratios of power (see above section). If we're talking about amplitudes, such as voltage or current (for example voltage gain), we need to adapt the formula slightly. This is outside the scope of this document, but the two formulae become:

$$G_{dB} = 20 \log_{10} \left(\frac{A_{meas}}{A_{ref}} \right)$$

To enter this into the calculator, the following is done:

- A_{meas} ÷ A_{ref} =

- 20 × log Ans =

One quick example is if we make a small-signal class-A amplifier. We put a signal of 3 Volts peak-to-peak into the input, and we observe a signal of 31 Volts peak-to-peak at the output. The voltage gain, in dB would be:

- 31 ÷ 3 =

- 20 × log Ans = 20.28480878 dB, approximately a gain of 20.3 dB.

13.3   Transmitting Station Case Study

Let's assume we have the following HF Station, showing the transmit direction only:

The transceiver is transmitting a signal of 15 Watts. The Linear Amplifier has a gain of 9 dB. The Low Pass Filter has a loss of 0.1 dB. The SWR Bridge has a loss of 0.3 dB. The Antenna Tuner a final loss of 0.6 dB. The feeder has a loss of 0.4 dB per metre, and there are 7 metres of feeder. The antenna is a 4 element Yagi with a gain of 6.85 dBd. What is the total effective radiated power?

My first suggestion is to convert the transceiver's 15 Watts into decibels:

$$G_{TX} = 10 \log_{10}\left(\frac{15}{1}\right) = 11.7609125906 \approx 11.8$$

So the transceiver is outputting 11.8 dBW. Here's where the decibels really come into our aid. Instead of multiplying or dividing by the different values, we simply add them together.

$$ERP_{dB} = G_{TX} + G_{Linear} + G_{LPF} + G_{SWR} + G_{ATU} + G_{Coax} + G_{Ant}$$

Substitute our values in

$$ERP_{dB} = 11.8 + 9 - 0.1 - 0.3 - 0.6 - (7 \times 0.4) + 6.85 = 23.85$$

So from our initial 11.8 dBW from the source transmitter, we have the equivalent of just 23.85 dBW effective radiated power over a dipole, due to the enhanced antenna and linear amplifier. As an example, we convert this back into Watts, and compare with our original 15 Watts:

$$\frac{P_{meas}}{P_{ref}} = 10^{\frac{23.85}{10}} = 242.661009508 \approx 243$$

So 243 times 1 Watt is obviously 243 Watts. Interestingly, if we turn the linear amplifier to bypass (set $G_{Linear} = 0$), we get an output power of 14.85 dBW (≈ 31 Watts).

All of these calculations are made much easier when working with decibels. It's instantly possible to see that we're loosing large amounts of power in this system, in the Feeder, LPF, SWR Bridge and ATU. Without these losses, our ERP would be approximately 73 Watts!

Chapter 14

Examples

Throughout the sections I have tried to add an example for each formula. Here in this section are a few more examples, with answers, to practice with... Try and calculate the number in **_red bold-italics_**. Some of the tables have missing values; this is intentional. Use or adapt the formula to calculate the answer with the given information.

14.1 RMS and Ohms Law

V_{ZP}	V_{RMS}
40	*28.28*
36	*25.46*
89	*62.93*
8	*5.66*
387	*273.65*
44	*31.11*
685	*484.37*
30	*21.21*
97	*68.59*

V_{PP}	V_{RMS}
17	*6.01*
80	*28.28*
52	*18.38*
160	*56.57*
86	*30.41*
182	*64.35*
36	*12.73*
53	*18.74*
29	*10.25*

V	I	R
27.3	0.354	77
7.55	0.181	41.7
187.3	1.718	109
12.8	*0.267*	47.9
54.3	*1.425*	38.1
85.9	*0.327*	263
43.2	0.930	*46.5*
33.5	4.831	*6.934*
6.8	1.159	*5.867*

14.2 Power and Potential Dividers

P	I	V	R
13.82	0.98	14.1	
93.48	1.41	66.3	
74.98	4.49	16.7	
31.05	0.72		59.9
153.66	2.80		19.6
180.52	7.43		3.27
787.96		87.2	9.65
24.36		30.1	37.2
3.47		12.4	44.3

V_{OUT}	R_1	R_2	V_{IN}
7.17	67	87	12.7
56.92	33	94	76.9
8.99	73	16	50.0
31.13	94	67	74.8
22.71	83	92	43.2
48.75	38	67	76.4
20.22	13	80	23.5
37.53	19	35	57.9
11.39	59	12	67.4

14.3 Reactance of Inductors and Capacitors

X_L	f	L
1214	1.61MHz	120μH
1616	433MHz	594nH
2.93	490KHz	952nH
179K	145MHz	197μH
12.18	7.05MHz	275nH
21.7K	1.91MHz	1.81mH
942	50 Hz	3H
6.7M	14.2MHz	75mH
11.9K	2.4GHz	793nH

X_C	f	C
133m	1.61MHz	120μF
619μ	433MHz	594nF
341m	490KHz	952nF
5.57μ	145MHz	197μF
82.1m	7.05MHz	275nF
46K	1.91MHz	1.81pF
1.06	50 Hz	3mF
149	14.2MHz	75pF
83.5μ	2.4GHz	793nF

14.4 Resistors in Series and Parallel

R_1	R_2	R_3	R_4	R_{series}	$R_{parallel}$
21	65			*86*	*15.87*
43	111	71		*225*	*21.58*
469	412	587	439	*1907*	*117.1*
189	403	991	819	*2402*	*99.98*

14.5 Inductors in Series and Parallel

L_1	L_2	L_3	L_{series}	$L_{parallel}$
82μH	93μH		*175μH*	*43.57μH*
401μH	3990nH		*405μH*	*3.95nH*
763nH	943nH	613nH	*2319nH*	*249.9nH*
1.89nH	4.37nH	2186pH	*8.45nH*	*823pH*

14.6 Capacitors in Series and Parallel

C_1	C_2	C_3	C_{series}	$C_{parallel}$
74pF	35pF		*23.8pF*	*109pF*
379nF	7910pF		*7.7nF*	*386nF*
974μF	537μF	584μF	*217μF*	*2.10mF*
120nF	0.1μF	98nF	*97.8pF*	*220nF*

14.7 Time, Frequency and Wavelength

T	f
231mS	*4.33*
963pS	*1.04GHz*
343μS	*2.92KHz*
741nS	*1.35MHz*
959μS	1043Hz
775pS	1.29GHz
55.3nS	18.1MHz
29.4μS	34KHz

f	λ
1043KHz	*288*
1.29GHz	*0.23*
18.1MHz	*16.6*
500KHz	*600*
13.6MHz	22.1
2.31GHz	0.13
15.0GHz	0.02
24MHz	12.5

14.8 Resonance

L	C	f
180nH	56nF	*1.59MHz*
209μH	95pF	*1.13MHz*
64nH	770pF	*22.7MHz*
83μH	55nF	*74.5KHz*
541nH	722pF	*8.05MHz*
1935pH	33pF	*630MHz*
2200nH	839μF	*3.70KHz*
10387nH	824μF	*1.72KHz*
607pH	12pF	*1.89GHz*

14.9 Transformers

V_P	N_P	N_S	V_S
47.4	71	41	*27.4*
71.2	22	47	*152.1*
85.3	47	17	*30.9*
88.5	54	30	*49.2*
51.1	20	27	*69.0*

I_P	N_P	N_S	I_S
75.9	67	35	*39.6*
25.4	19	8	*10.7*
45.7	34	21	*28.2*
31.6	54	16	*9.4*
9.76	11	12	*10.6*

Z_P	N_P	N_S	Z_S
249	45	35	*150.6*
481	97	8	*3.3*
939	21	21	*939*
117	27	16	*41.1*
157	7	12	*461.4*

14.10 Transistors

i_B	i_C	i_E
0.012	0.473	*0.485*
0.007	0.059	*0.066*
0.009	0.383	*0.392*
0.034	1.241	*1.275*
0.021	1.539	*1.560*

i_B	i_C	β
0.012	0.473	*39.42*
0.007	0.059	*8.428*
0.009	0.383	*42.56*
0.034	1.241	*36.50*
0.021	1.539	*73.29*

14.11 Decibels

P_{in}	P_{out}	G_{dB}	V_{in}	V_{out}	G_{dB}
3.9	70.1	*12.55*	6.3	8.5	*2.60*
1.9	69.2	*15.61*	9.4	4.7	*-6.02*
2.3	87.3	*15.79*	4.7	7.3	*3.82*
4.9	2.87	*-2.32*	7.4	9.5	*2.17*
4.8	22.7	*6.75*	4.2	9.4	*7.00*

Chapter 15

Conclusions

Finally, all that remains is to wish you good luck. I hope to work you on air with your new full callsign!

73

George Smart
M1GEO

http://www.george-smart.co.uk/
m1geo@george-smart.co.uk

15.1   Copyright

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15.2   Declaration of Originality

I declare that all material presented in this booklet is my own work except where explicitly and individually indicated in the text. This includes ideas and opinions described in the text, figures, and computer programs. In this booklet, all images come from Wikipedia or were created for this document by me, George Smart. All images are in the public domain. While I have done the very best to check the information and calculations here, there may be mistakes – please report them via the email address above. All numerical examples are based on random values, although I have tried to choose realistic numbers and amateur radio related examples.

15.3   Version History

Since this document was put online in November 2012, it has attracted feedback and has undergone minor corrections. This table below documents changes.

Version	Date	Changes	Acknowledgements
3	07 February 2013	Chapter 3, RMS. Incorrect calculation.	Larrie Sutliff, W2UL. Manuel Gonzalez, N2MAV.
2	31 December 2012	Chapter 11, Transformers. Incorrect formula for I_S.	Lee Hudson, M0LMH.
1	21 November 2012	Original	

Thank you.