.

Most times it makes no difference

Sometimes it does

- In a tuned circuit, variation could be critical to resonance
- In a filter it may change the cut-off frequency
- In an amplifier, to much gain could result in harmonics

Where circuits require precise performance there is normally some kind of adjustment

- Fine tune trimmer capacitors
- Variable inductors
- Pre-set potentiometers

$$Tolerance = 10 \times 10^6 \times \frac{10}{10^6} = 10 \times 10 = 100Hz$$

Repeat of Intermediate point:

- All components are made to a tolerance
- Value may be higher or lower than its marking
- Sometimes expressed in % terms
  - 100Ω with 10% tolerance = between 90-110Ω
- Sometimes expressed in ppm = parts per million
  - 10MHz crystal with 10ppm tolerance
  - 10 million Hz so 10 x 10ppm gives +/- 100Hz = tiny %
- For transistors, data sheets show minimum, maximum and typical values

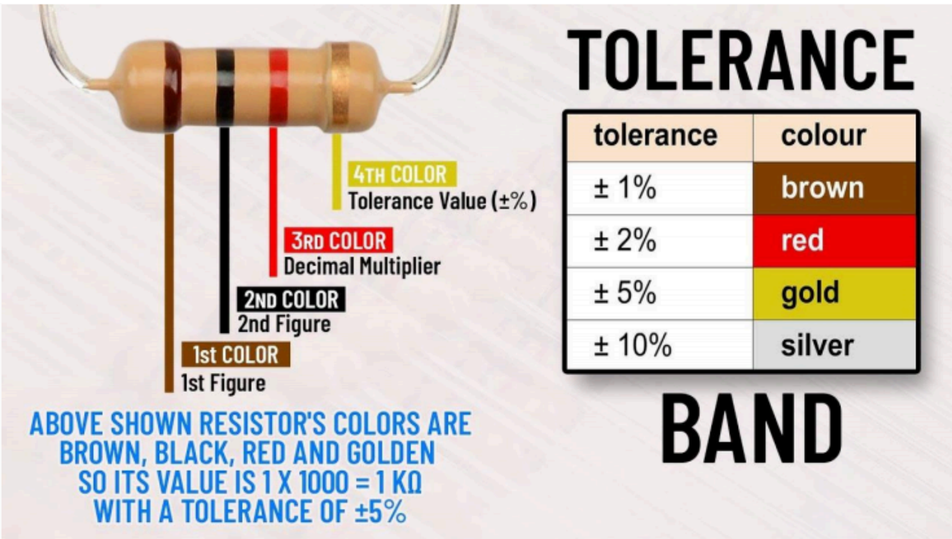
2a.1 (3/4) • Fundamental theory • id:PoFykgkR

brown $\pm$ 1%

red $\pm$ 2%

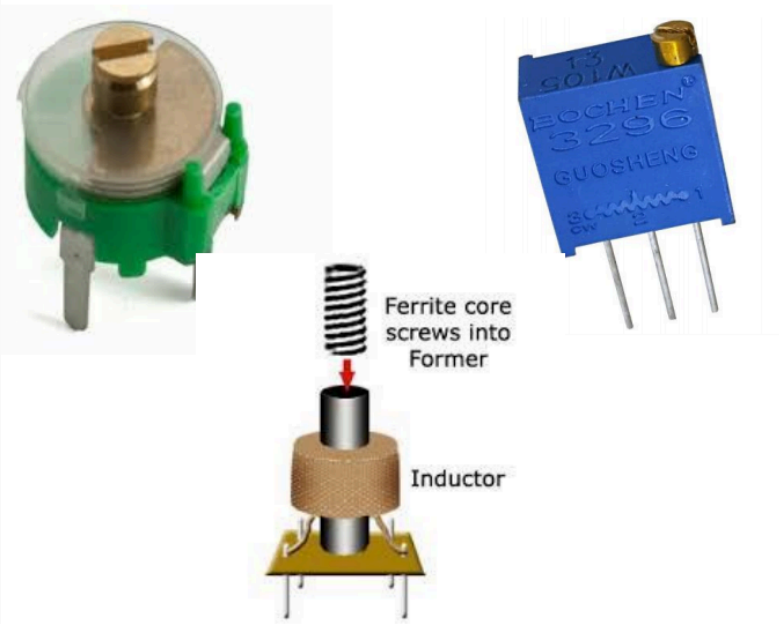
gold $\pm$ 5%

silver $\pm$ 10%



2a.1 (4/4) • Fundamental theory • id:Bb7MwMw9

here are some examples



2d.1 (1/4) • Reactive components • id:kEyJnElw

$$C = \frac{k \cdot A}{d}$$

- where C is Capacitance in Farads
- k is Permittivity constant of the dielectric
- A is the Area of the plates in square metres
- d is Distance between the plates in metres

2d.1 (2/4) • Reactive components • id:WUxQUz1C

Capacitance **halves**

$$C \propto \frac{1}{d}$$

Inverse relationship

2d.1 (3/4) • Reactive components • id:iOXUtAs9

Capacitance **doubles**

$$C \propto A$$

Direct relationship

2d.1 (4/4) • Reactive components • id:snGJZdyD

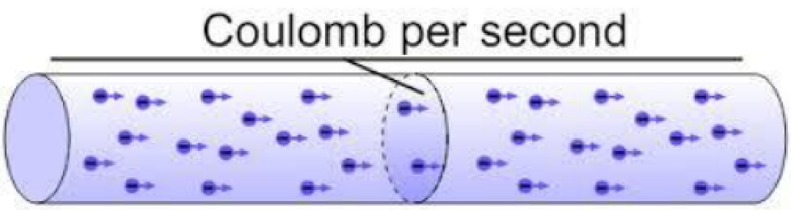
Yes it is, on the third row from the top. It should be written as $C = \frac{k \times A}{d}$ and not with A as a subscript

2d.1 (1/2) • Reactive components • id:erA72lhb

The Coulomb is the quantity of electricity or charge:

$$Q = current \times time$$

and if one Coulomb of charge passes a point every second, 1 Amp of current is flowing. Coulomb is the charge from $6 \times 10^{18} electrons$ Q is not to be confused with Q as ameasure of selectiviity or magnification factor.



2d.1 (2/2) • Reactive components • id:PzSmDiD6

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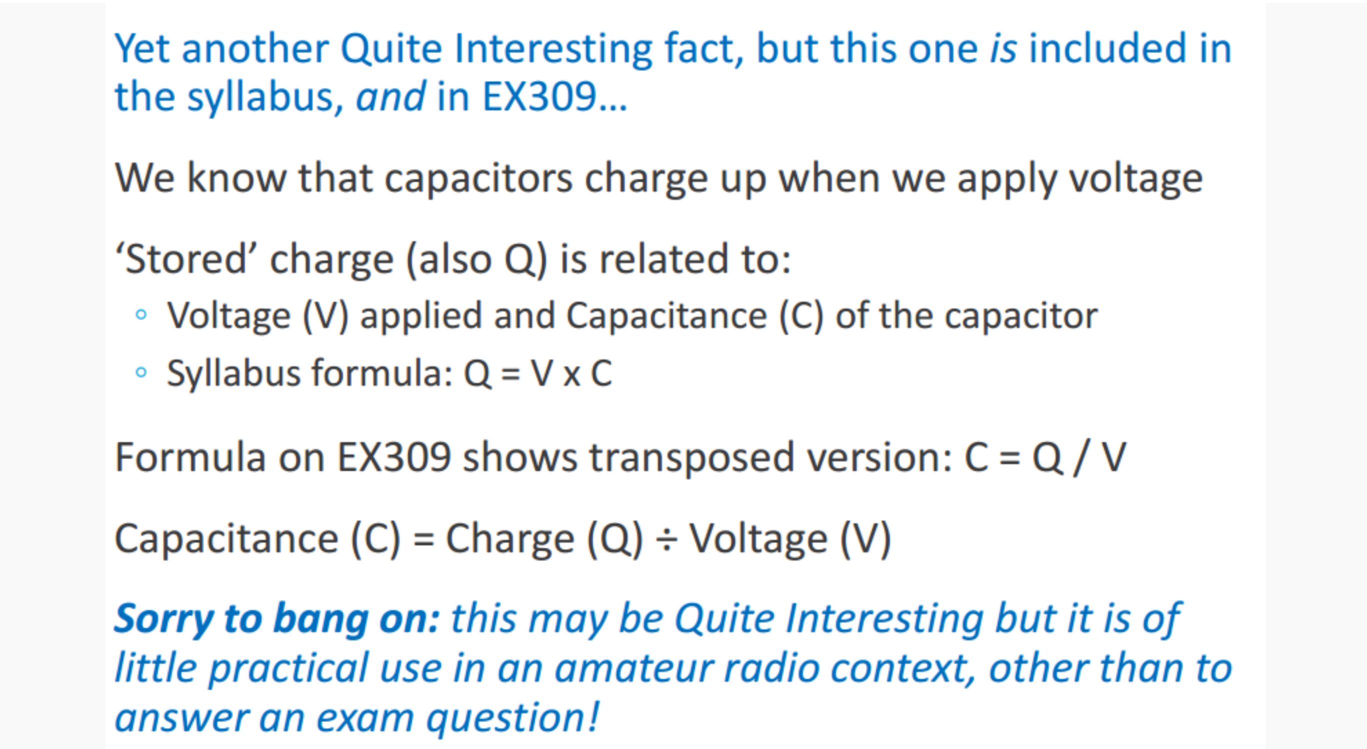

2d.2 (1/2) • Reactive components • id:jP8IiNpC

.

Insulation layer = dielectric

Many different materials used:

- Air
- Ceramic
- Mica
- Polystyrene
- Polyester

Each has a different k value (see formula)

- Not in syllabus, but Air = 1, ceramic = 5

Man-made dielectrics tend to be more 'lossy'

Losses tend to increase with frequency in use

2d.2 (2/2) • Reactive components • id:8t67KqZJ

The low dielectric constant version of the ceramic capacitor fits the bill. Not to be confused with the high dielectric version which is not suitable for higher RF frequencies.

Ceramic capacitors come in two types, those with a low dielectric constant having low values in the 10s and 100s of picofarads. These have a low loss, and are stable and suitable for RF use. Also suitable are mica capacitors comprising a mica wafer and metalised film (usually silvered) sandwich. The 'hi-k' ceramic capacitors use ceramics of high dielectric constant. These allow relatively high capacitances in small volumes but are lossier and not suitable for higher RF frequencies.

Very large capacitances require very thin dielectrics which are formed chemically in electrolytic capacitors. An aluminium foil forms one plate of the capacitor but the other plate is a conductive chemical paste on a foil backing. The dielectric is an oxide insulating layer. These capacitors are polarised and must not be subjected to either reverse polarity or over-voltage.

2d.3 (1/2) • Reactive components • id:E2bs6PI2

The capacitor can break down and be destroyed. Effects range from a small pop to a big bang. Normally the voltage will be written on the capacitor, otherwise contact the supplier etc.

All capacitors have a Safe Working Voltage

- Can ‘break down’ if exceeded = destroyed

2d.3 (2/2) • Reactive components • id:xLIq4u_V

.

2d.4 (1/3) • Reactive components • id:FOUzLyD4

.

Recall that an inductor is a coil of wire

Stores energy in magnetic field

Inductance unit = Henry

Value depends on:

- Number of turns
- Diameter of coil
- Length of coil
- Any core, e.g. ferrite

Now need to dig a bit deeper...

2d.4 (2/3) • Reactive components • id:OZVRnz0L

.

Inductance of coil = **self-inductance**

As current through wire increases a magnetic field is generated – principle of an electro-magnet

That magnetic field induces a EMF in the wire **in the opposite direction** – effectively pushing back

- Known as **'Back EMF'**

Only present when current is changing; a steady current will have constant magnetic field so no back EMF

2d.4 (3/3) • Reactive components • id:Djmqkm8X

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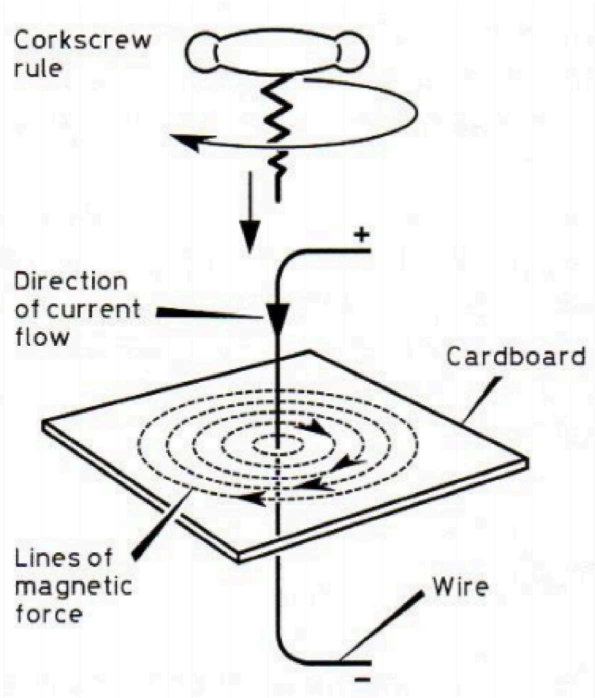

2d.7 (1/2) • Reactive components • id:PDGB_68f

.

Because capacitors take time to charge, and inductors produce Back EMF, **changes in voltage and current not instant**

Time constant = τ is used to calculate how long changes will take

All real circuits will include some resistance

Rise and fall of V & I related to inductance or capacitance and resistance

2 Formula in EX309:

- $\tau = C \times R$
- $\tau = L \div R$

Note 1: ***τ is time taken to reach about 66% of rise, or fall***

Note 2: ***maximum, or zero, only reached after 5 x τ!***

2d.7 (2/2) • Reactive components • id:DGnw4qzj

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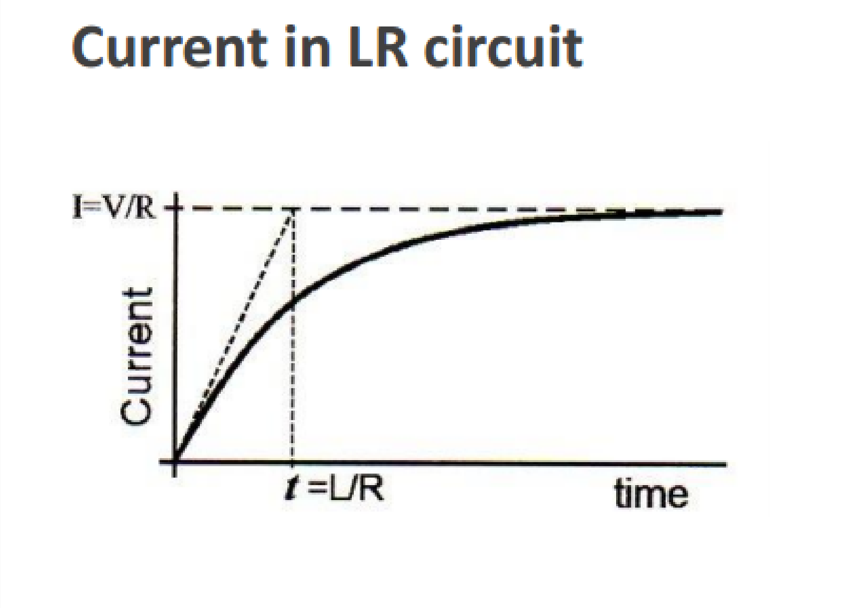

2d.7 • Reactive components • id:jJL0xDVW

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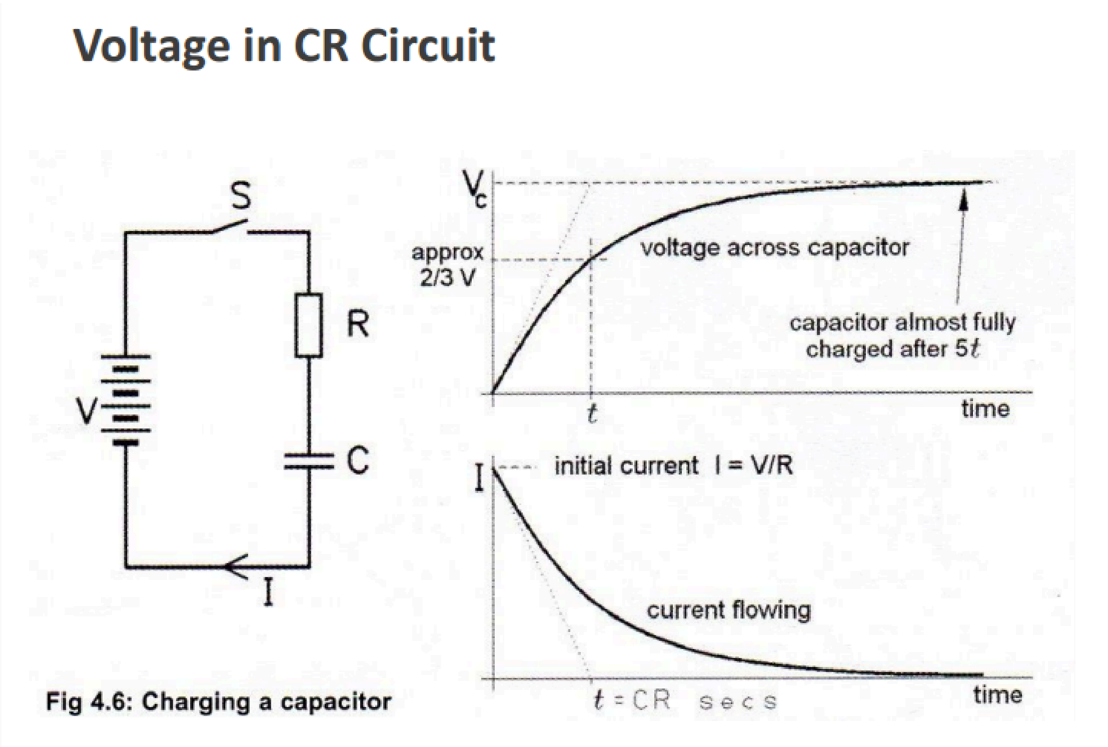


2e.3 (1/2) • AC theory • id:K3f1UiBo

.

Intermediate recap:

- In circuits with pure C or pure L
- Voltage & Current have 90^0 phase difference

Now need to know which leads which…

In Capacitor C, current I, leads voltage V = CIV

Voltage V, leads current I, in an Inductor L = VIL

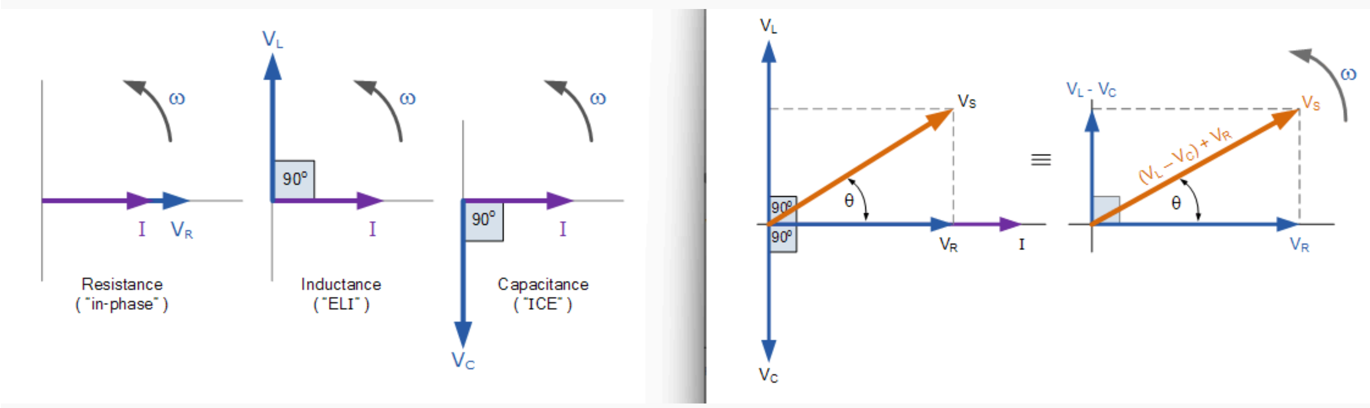
Combine to give 'the CIVIL law':

- *CIV = in C, I is leading V*
- *VIL = V is leading I, in L*

Note: You can have circumstances when difference is NOT 90^0 but syllabus does not cover other angles

2e.3 (2/2) • AC theory • id:UHcSkdol

The amplitude of the source voltage across the components in the circuit is made up of the three component voltages, V_R, V_L and V_C, with the current common to all three components. The vector diagrams will therefore have the **current vector** as their reference, with the three voltage vectors being plotted with respect to this reference.



2e.3 (1/5) • AC theory • id:OB47yhKe

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

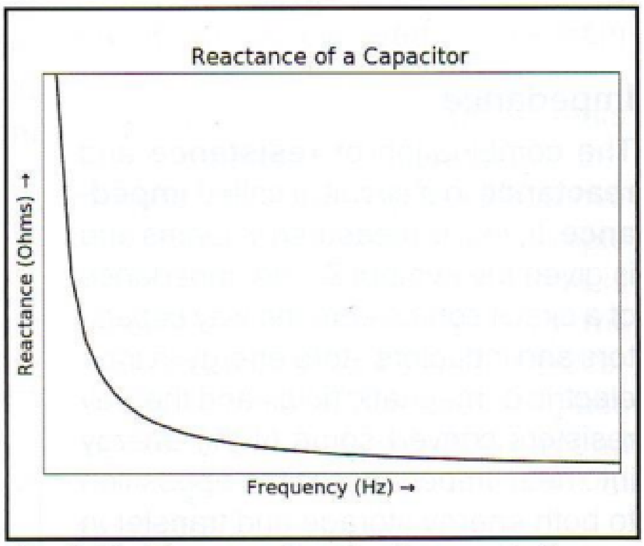


Fig 4.30: The reactance of a capacitor vs frequency

2e.3 (2/5) • AC theory • id:cFx7kOmd

$$X_L = 2\pi f L$$

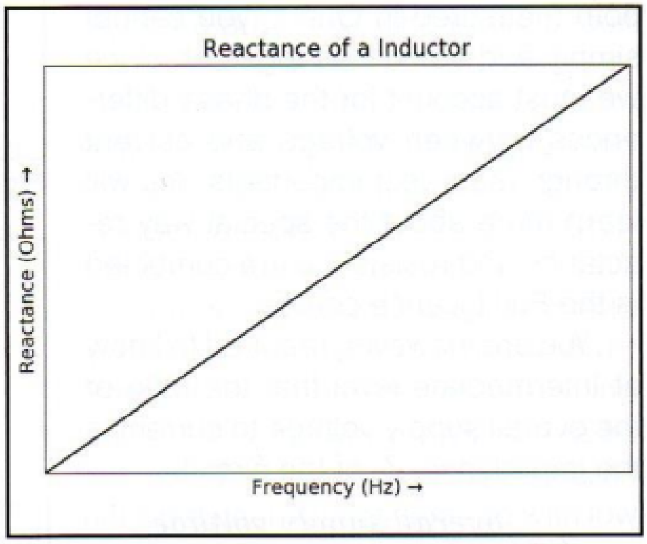


Fig 4.31: The reactance of an inductor is linear with frequency

2e.3 (3/5) • AC theory • id:BCHjk6FS

It is two separate keystrokes. Press SHIFT then press EXP. Any problems use 3.1

2e.3 (4/5) • AC theory • id:5IC4HSSk

$$X_L = 2\pi f L$$

Reactance of 10µH inductor at 7MHz?

X_L = 2 x π x f x L

- 2 number in formula
- [x] multiply by
- [Shift]) two keys for Pi
- [x10ˣ]) or [EXP] on a clone calculator
- [x] multiply by
- 7 for 7MHz
- [x10ˣ] or [EXP] on a clone calculator
- 6 to represent the MHz
- [x] multiply by
- 10 for 10µH
- [x10ˣ] [EXP] on a clone calculator
- [-]
- 6 to represent the µH
- [=] to get the answer
- 439.82… round up to 440 Ω

2e.3 (5/5) • AC theory • id:t7V6D5iL

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

Reactance of 22pF capacitor at 10MHz?

$X_C = 1 \div (2 \times \pi \times f \times C)$

- 1 number in formula
- [÷] divide by
- [(] open bracket
- 2 number in formula
- [x] multiply by
- [Shift] two keys for Pi
- [x10^x] [EXP] on a clone calculator
- [x] multiply by
- 10 for 10MHz
- [x10^x] [EXP] on a clone calculator
- 6 to represent the MHz
- [x] multiply by
- 22 for 22pF
- [x10^x] [EXP] on a clone calculator
- [-]
- 12 to represent the pF
- [)] close the bracket
- [=] to get the answer
- 723.431… round down to 723 Ω

2e.3 • AC theory • id:MIZ9XKFh

.

2e.4 (1/5) • AC theory • id:XHrZd8SU

.

Coupling = linking between stages

- Allows AC to be passed but DC to be blocked
- Oscillator may be working at 5V
- Power Amp working at 50V
- Want RF to pass but not the DC
- Use capacitive coupling

2e.4 (2/5) • AC theory • id:GBtkMjhk

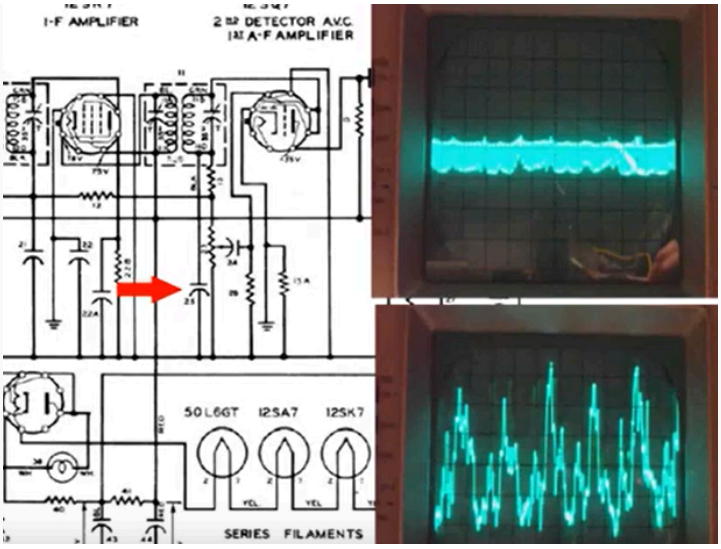
.

Decoupling = taking AC to ground

- Maybe have unwanted RF on DC supply
- May want RF to by-pass a resistor
- Use capacitive decoupling – maybe think of it as coupling to ground?

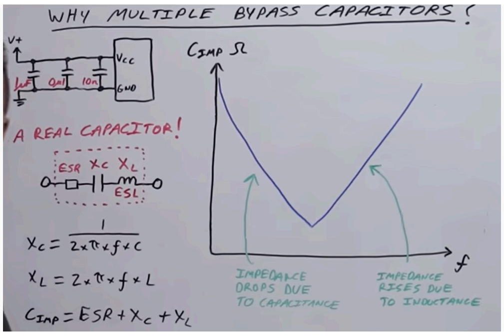
2e.4 (3/5) • AC theory • id:UOpfSJqm

The image shows the RF bypass being handled by a capacitor. The top oscilloscope image shows an audio signal being polluted with RF, making it very difficult to hear the audio. With the RF bypass capacitor, the RF is taken to ground, and the audio can be clearly heard.



2e.4 (4/5) • AC theory • id:V3fn3QoI

In an ideal world bypass wouldn't be needed, but connections etc have parasitic inductance, capacitance and resistance, that can affect where the power is going to, and be seen as 'ringing' on a trace. A bypass capacitor is normally placed just before the components that will use the voltage, so it's as clean as possible. It can also act as a local reservoir of current, taken from the capacitor. Multiple capacitor bypass can spread the resonant frequency range.



2e.4 (5/5) • AC theory • id:a52zD3NT

Any time we want to take unwanted AC to ground, such as unwanted RF on a DC power supply, we can use a bypass or decoupling capacitor.

2e.5 (1/2) • AC theory • id:x8Fj1aqF

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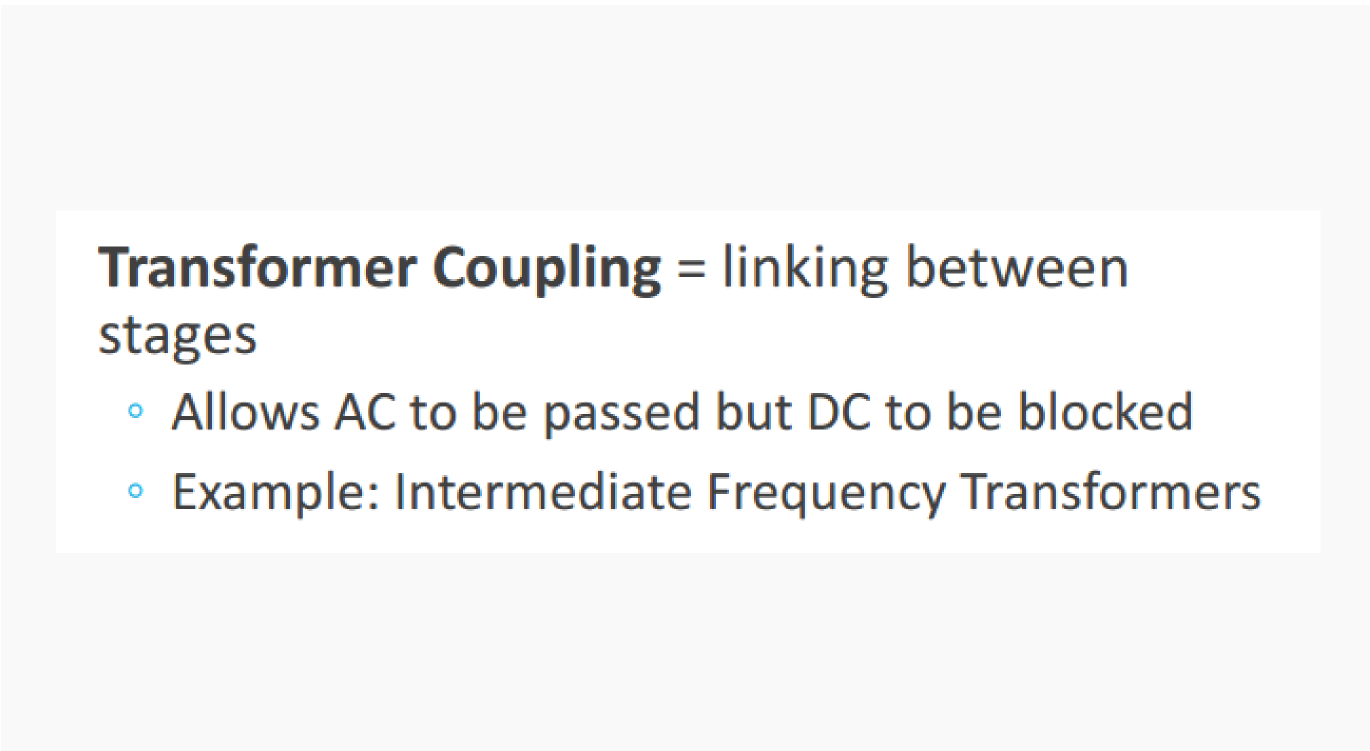

2e.5 (2/2) • AC theory • id:-ybShg7h

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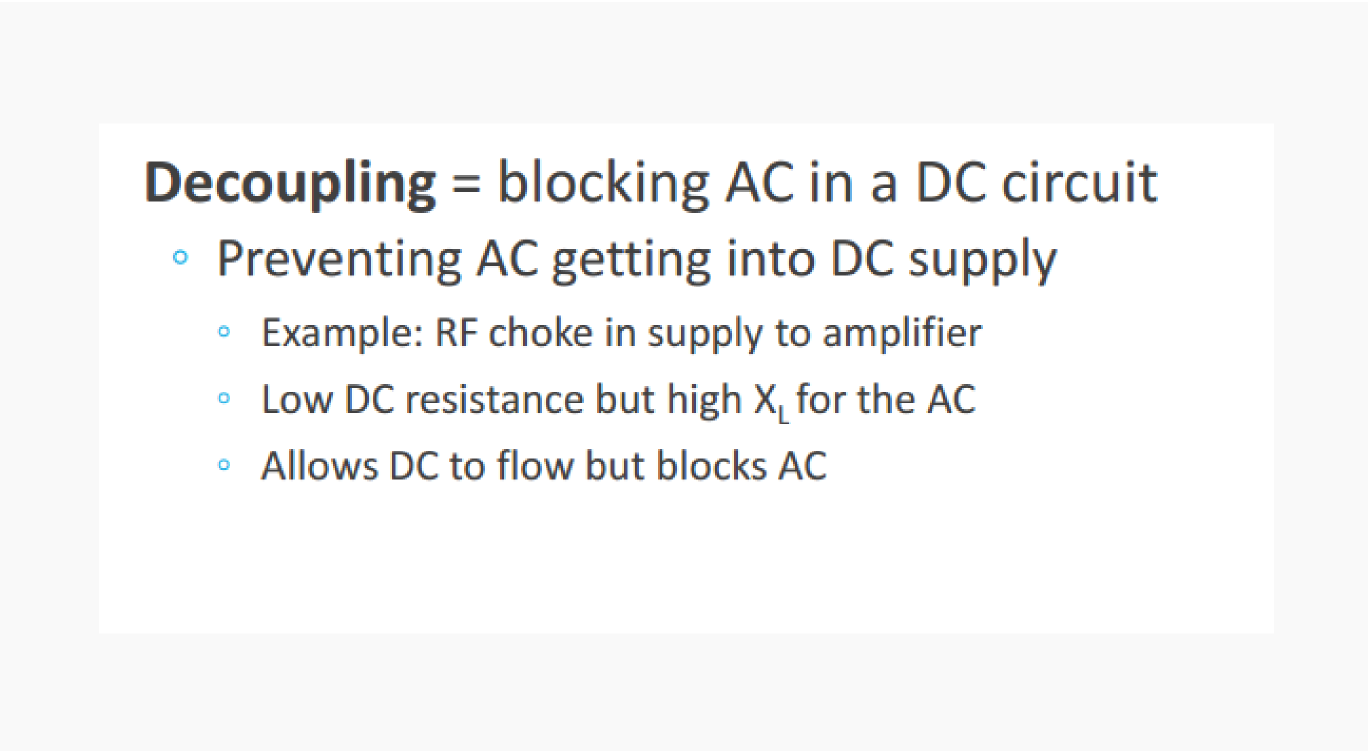


2e.6 (1/5) • AC theory • id:7YKuHqny

$$\text{Impedance } Z = \sqrt{(R^2 + X^2)}$$

This often means a two step calculation:

- work out reactance of inductor or capacitor from component values
- then work out impedance

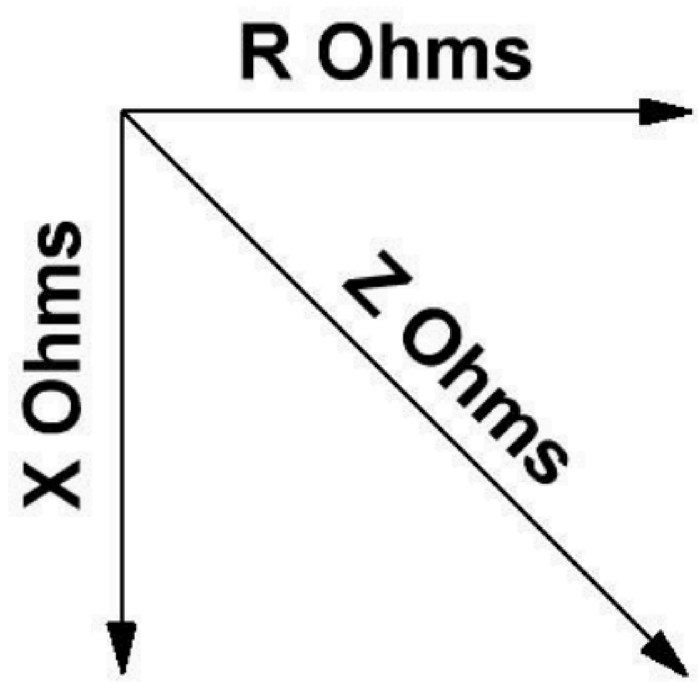
Sanity check:

Z will always be more than either R or X but will be less than R + X.

for a 3,4,5 triangle, 5 is more than 3 or 4, but less than 3+4.

2e.6 (2/5) • AC theory • id:Kd_v9eaD

A right angled triangle.



2e.6 (3/5) • AC theory • id:WM6LX6G-

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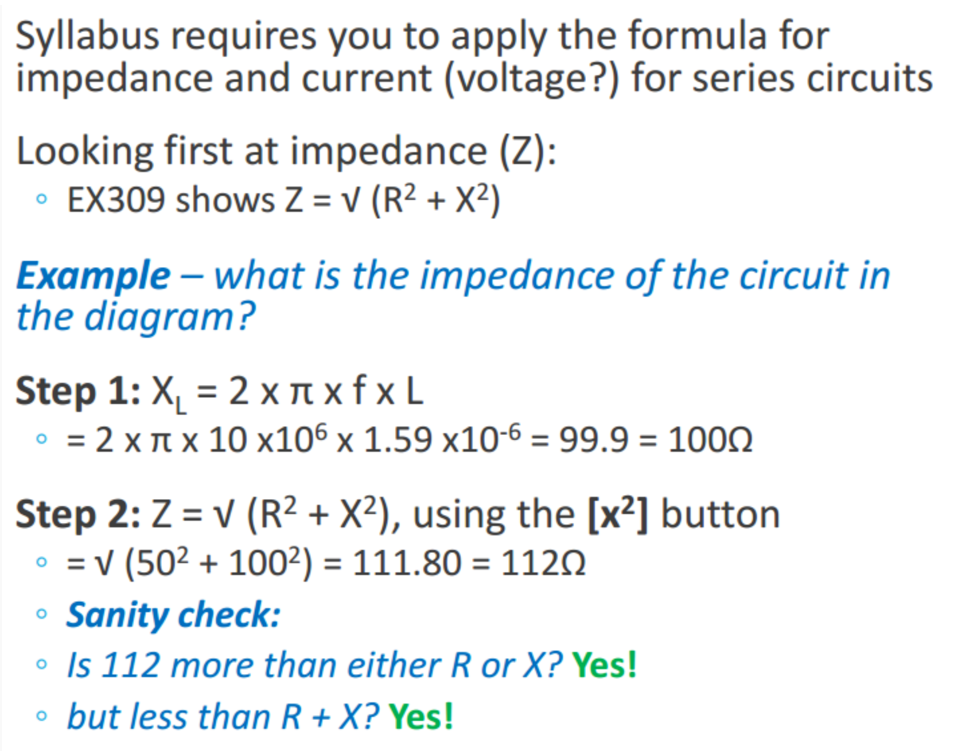

2e.6 (4/5) • AC theory • id:D_qymJnT

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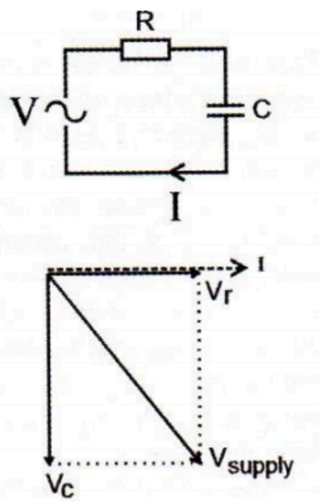


'Simple' 3, 4, 5 example:

What is V_{supply} if:

$V_R = 3V$

$V_C = 4V$

Cannot simply add V_R & V_C to get 7!

Using formula & $[x^2]$ button

$\sqrt{(3^2 + 4^2)} = \sqrt{(9 + 16)} = \sqrt{(25)}$

$= 5V$

Sanity check:

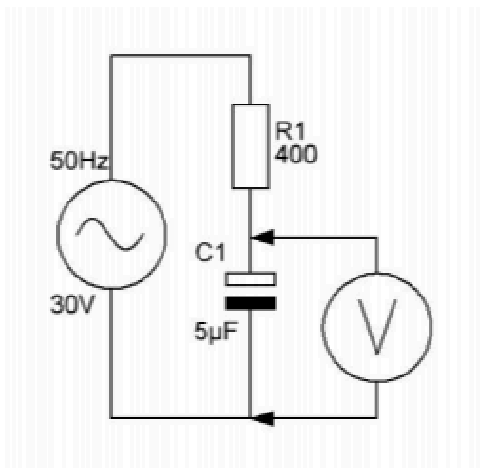
Is 5 more than either Vr or Vc? **Yes!**

Is 5 less than Vr + Vc? **Yes!**

2e.6 (5/5) • AC theory • id:nODdsBIO

get the worked example in the weekly instructions

Annex: Volts in an RC circuit: a worked example of a REALLY NASTY question.



In the diagram the supply is $30V_{RMS}$ at 50Hz, the resistor is 400Ω and the capacitor is 5µF. What is the potential difference being measured across the capacitor?

2h.1 (1/4) • Tuned circuits and resonance • id:-cve6QhE

.

Intermediate recap, RF tuned circuits:

- formed from an inductor and a capacitor
- Can be in series or in parallel
- Resonant frequency is when X_C and X_L are equal
- Can be shown on a graph
- 'Best energy transfer' is at resonant frequency

Series tuned circuit has low Z at resonance

- allows resonant frequency to pass but stops all others

Parallel tuned circuit has high Z at resonance

- stops the resonant frequency but allows all others to pass:
- Example of a trap dipole to remember which is which

2h.1 (2/4) • Tuned circuits and resonance • id:80kswhtQ

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

New: Full syllabus requires you to be able to calculate the resonant frequency, symbol 'f'

Formula in column 3 EX309:

- f = 1 ÷ (2 x π x √ (L x C))

Only 1 formula: applies to both series and parallel

Take it one step at a time and it is not too difficult

General rule to remember about tuned circuits:

- *Increasing component values = decreases resonant frequency*
- *Decreasing component value = increases resonant frequency*
- *Big components, low frequency, tiny components high frequency*
- *May mean no calculation required!*

2h.1 (3/4) • Tuned circuits and resonance • id:Icrs9YHB

.

Formula in column 3 EX309:
- f = 1 ÷ (2 x π x √ (L x C))

Possible calculations:
- straightforward question about the resonant frequency, or
- Given resonant frequency and one component to find the other

Can key in bottom line, then use **[x^{-1}]**

You can transpose to:
- C = 1 ÷ (4 x π^2 x f^2 x L)
- L = 1 ÷ (4 x π^2 x f^2 x C)

Or, use the 4 answers given to get back to f =

Possible complications?
- Could have more than one capacitor or inductor
- May need to use series/parallel formula to get to single value

2h.1 (4/4) • Tuned circuits and resonance • id:YIWQ4xfJ

.

What is resonant frequency of 22pF capacitor with 10uH inductor?

- **1** top line
- **[÷]** divided by
- **[(]** open bracket
- **2** number from formula
- **[x]** multiply by
- **[Shift]** two keys for Pi
- **[x10ˣ]** [EXP] on a clone calculator
- **[x]** multiply by
- **[√]** square root of (also need to add [(] on clone)
- **10** for the 10uH L
- **[x10ˣ]** [EXP] on a clone calculator
- **[-]**
- **6** to represent micro Henry
- **X**
- **22** for the 22pF C
- **[x10ˣ]** [EXP] on a clone calculator
- **[-]**
- **12** to represent pico Farad
- **[>]** right hand direction pad to close square root ([)] on older Casios & clones)
- **[)]** close bracket second time
- **[=]** equals 10730224.07
- **[ENG]** engineering number = 10.7302... x10^6 = 10.73MHz

2h.2 (1/3) • Tuned circuits and resonance • id:s7y_uZJc

See Full Manual pp29-30

Lumps of Quartz with piezo-electric properties

Used to form resonators

Can be used in place of a tuned circuit in oscillators or filters

- Commonly used in SSB filters

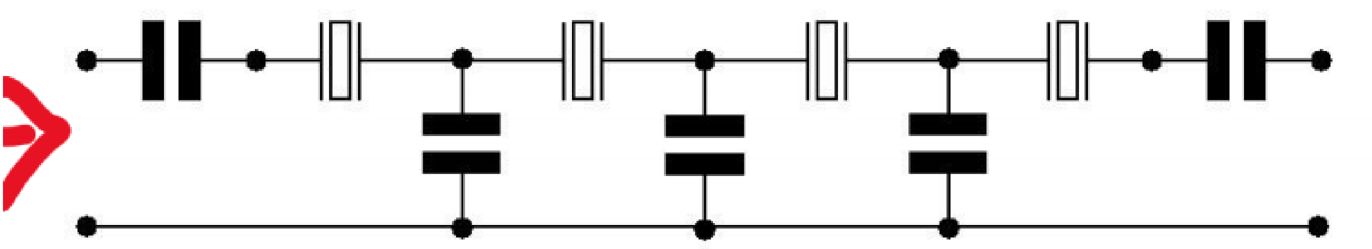
New: equivalent circuit shows series and parallel capacitors

Can work in two 'modes'; series or parallel loading

Must be used in correct mode to obtain the design frequency

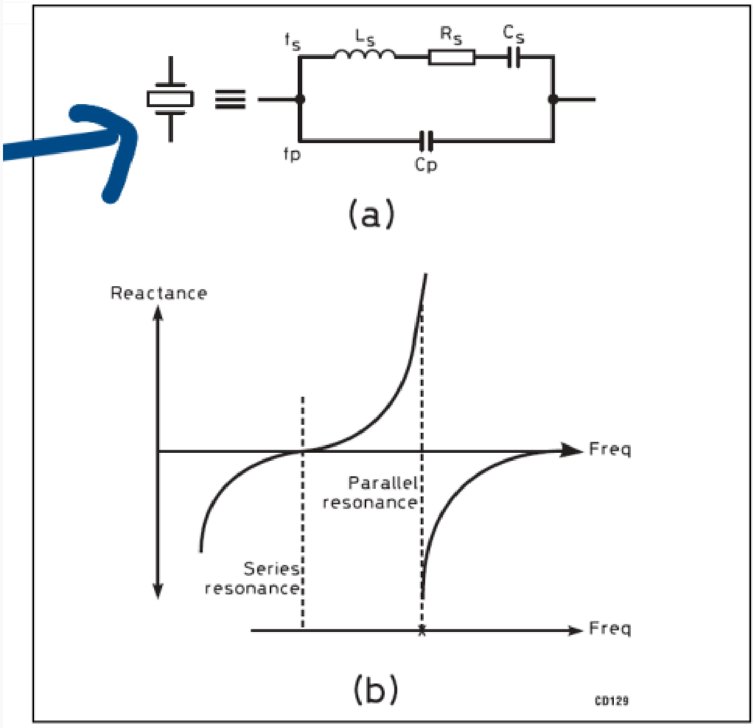
2h.2 (2/3) • Tuned circuits and resonance • id:0S0usOAm

See Full Manual pp29-30



2h.2 (3/3) • Tuned circuits and resonance • id:knIdQzuu

See Full Manual pp29-30



2h.4 • Tuned circuits and resonance • id:hQ5vWwHT

Calculation steps:

1. calculate $X_C = 1/2\pi fC = 500\Omega$ and $X_L = 2\pi fL = 500\Omega$
2. The combined reactance of X_L and X_C is zero, so that leaves only the circuit resistance to oppose the flow
3. $I = \frac{2mV}{2\Omega} = 1mA$
4. Both L and C will be passing the 1mA of current, so there will be a voltage across each reactive component of $1mA \times 500\Omega = 500mV$
5. RADIO MAGIC: 250 times input voltage, and MAGNIFICATION Q at work
6. A shorter path to finding Magnification $Q = \frac{X_L}{R}$ or $\frac{X_C}{R} = \frac{500}{2} = 250$

2h.4 • Tuned circuits and resonance • id:TuDkF5TC

stuff

2h.4 • Tuned circuits and resonance • id:bSZoHasf

stuff

2h.4 • Tuned circuits and resonance • id:ck-ql2VL

stuff

2h.4 • Tuned circuits and resonance • id:pnYosChc

stuff

2h.5 • Tuned circuits and resonance • id:gsL6QJgR

$R_D = //fracLCR$

Dynamic Resistance

Parallel tuned circuit at resonance:

- $X_C = X_L$
- Xs do not cancel, kind of multiply = High Z

In theory no AC should flow, but inductor has a low series resistance

Not pure X_L so Z is high but not infinite

At resonance, the tuned circuit has a "dynamic resistance" R_D

R_D is effective resistance of the tuned circuit at resonance

Explicit syllabus point to calculate R_D removed but…

Formula is in column 3 of EX309: $R_D = L \div (C \times R)$

For more detail see RSGB Handbook 'Principles'

- *It shies away from full explanation!*

7a.1 • Good operating practices and procedures • id:undefined

Transmitting on one frequency and listening on another, about 5 to 10kHz away

Technique to help pick out stations in a 'pile up'

Pile up = many stations all calling you at once

Listening over a few kHz spreads out the callers, easier for DX station to pick them out.

Callers continue to listen on transmit frequency – when DX replies you can hear their report

If you hear *'…calling CQ and listening 5 up'*

- Set transmit frequency to 4 - 6 kHz higher
- Use RIT to listen on original frequency
- Or set up radio to work split (check rig manual)

7a.8 • Good operating practices and procedures • id:undefined

Used to be in Licence section of Syllabus

Changed because there is no longer anything in the Licence that requires you to **carry out tests from time to time**

Now seen as 'good operating practice'

- Part of Operating, not Licence Conditions

Test can include:

- Looking for harmonics or other spurious emissions
- Checking for drift or excess bandwidth

Key Points

- No requirement for 'perfect' transmissions, just no 'undue interference'
- Idea is to check everything seems OK, from time to time (e.g. when you change your equipment)

Ofcom Guidance Document, section 4.1, page 12 says:

- *"The Licence requires that any radio equipment is designed, constructed, maintained, and used so that its use does not cause any undue interference to any other wireless telegraphy user. Licensees therefore need to ensure that all measures are taken for this not to occur,* ***this should include testing the radio equipment from time to time.*** *"*

7b.1 (1/7) • Band plans • id:undefined

Produced by IARU = international agreements

Not universal across the globe – there are variations between Regions, and countries

Recommended in UK but some countries make them mandatory – need to check if travelling

Two provided in **EX309; 600m & 60m**

- Bands only available to Full Licence holders

Notes to the bandplans also in EX309

- Not mentioned in syllabus
- Know they are there
- You also need to be able to find information
- ***Look it up!***

7b.1 (2/7) • Band plans • id:undefined

5 MHz (60m)	Available Bandwidth	UK Usage
5258.5 - 5264.0 kHz	5.5 kHz	5262 kHz - CW QRP Centre of Activity
5276.0 - 5284.0	8 kHz	5278.5 kHz - may be used for UK emergency comms traffic
5288.5 - 5292.0	3.5 kHz	Beacons on 5290 kHz (Note-2)
5298.0 - 5307.0	9 kHz	
5313.0 - 5323.0	10 kHz	5317 kHz - AM 6kHz max. bandwidth
5333.0 - 5338.0	5 kHz	
5354.0 - 5358.0	4 kHz	Within WRC-15 Band
5362.0 - 5374.5	12.5 kHz	Partly within WRC-15 band, WSPR
5378.0 - 5382.0	4 kHz	
5395.0 - 5401.5	6.5 kHz	
5403.5 - 5406.5	3 kHz	

7b.1 (3/7) • Band plans • id:undefined

Unless indicated, usage is all-modes (necessary bandwidth to be within channel limits)

Note 1: Upper Sideband is recommended for SSB activity.

Note 2: Activity should avoid interference to the experimental beacons on 5290 kHz

Note 3: Amplitude Modulation is permitted with a maximum bandwidth of 6kHz, on frequencies with at least 6kHz available width

Note 4: Contacts within the UK should avoid the WRC-15 band (5351.5 - 5366.5 kHz) if possible

LICENCE NOTES: Full Licensees only Secondary User: 100W max

Note that specific conditions regarding operating, transmission bandwidth, power and antennas are specified in the Licence.

7b.1 (4/7) • Band plans • id:undefined

472 kHz (600m)	Necessary Bandwidth	UK Usage
IARU Region-1 does not have a formal band plan for this allocation, but has a usage recommendation (Note-1)		
472-479kHz (Note-2)	500	CW, QRSS and narrow-band digital modes (Note-1)

Note-1: Usage recommendation: - 472-475 kHz CW-only 200Hz max BW, 475-479 kHz - CW & Digimodes
Note-2: It should be emphasised that this band is available on a non-interference basis to existing services. UK amateurs should be aware that some overseas stations may be restricted in their use of transmit frequency in order avoid interference to nearby radionavigation service Non-Directional Beacons
LICENCE NOTES: Amateur Service Secondary User. Full Licensees only - 5 Watts eirp maximum.

7b.1 (5/7) • Band plans • id:undefined

R.R. 5.80B The use of the frequency band 472-479 kHz in Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia and Yemen is limited to the maritime mobile and aeronautical radionavigation services. The amateur service shall not be used in the above-mentioned countries in this frequency band, and this should be taken into account by the countries authorizing such use. (WRC 12)

Necessary bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

All Modes: CW, SSB and those modes listed as Centres of Activity, plus AM. Consideration should be given to adjacent channel users.

Image Modes: Any analogue or digital image modes within the appropriate bandwidth, for example SSTV and FAX.

Narrowband Modes: All modes using up to 500Hz bandwidth, including CW, RTTY, PSK, etc.

Digimodes: Any digital mode used within the appropriate bandwidth, for example RTTY, PSK, MT63, etc.

Sideband usage: Below 10MHz use lower sideband (LSB), above 10MHz use upper sideband (USB). Note the lowest dial set- tings for LSB Voice modes are 1843, 3603 and 7043kHz on 160, 80 and 40m. Note that on (5MHz) USB is used.

Amplitude Modulation (AM): AM with a bandwidth greater than 2.7kHz is acceptable in the All Modes segments provided users consider adjacent channel activity when selecting operating frequencies (Davos 2005).

Extended SSB (eSSB): Extended SSB (eSSB) is only acceptable in the All Modes segments provided users consider adjacent channel activity when selecting operating frequencies.

Digital Voice (DV): Users of Digital Voice (DV) should check that the channel is not in use by other modes (CT08_C5_Rec20).

FM Repeater & Gateway Access: CTCSS Access is recommended. Toneburst access is being withdrawn in line with IARU-R1 recommendations.

MGM: Machine Generated Modes indicates those transmission modes relying fully on computer processing such as RTTY, AMTOR, PSK31, JTxx, FSK441 and the like. This does not include Digital Voice (DV) or Digital Data (DD).

WSPR: Above 30MHz, WSPR frequencies in the band plan are the centre of the transmitted frequency (not the suppressed carrier frequency or the VFO dial setting).