Week 3: Bipolar Transistors Mon 2/10 H&H Labs 4&5

READ p 90-93, 102, 115&6. Last week unfinished? Use make-up!

DO NOT DO: Lab 4-7,8; ONLY DO 5-2; optional 4-7.

Typical transistor: current gain "β" ~ 100. AC or DC

"trans-(re)sistor", an impedance matcher, look into each hole:

Look into input, want hi Z_{input}, easy to drive from previous.

x100 more than next stage.

gives 100x lower Z_{output} ideally: Z_{in} hi, Z_{out} low p96

Measuring Z: dial resistor box to reduce V by x2

Input voltage dynamic range:

set by 0.6v V_{BE} forward Si diode

Output voltage dynamic range (≡compliance): p140

set by 2 voltage supply rails

X-ister switch: when "on", i_{CE} current saturated to get $V_{CE} \rightarrow 0$

Bias Rs set DC operating "sweet" spot, then optimize AC gain.

C_{in} & C_{out} block external offsets to preserve DC bias voltages

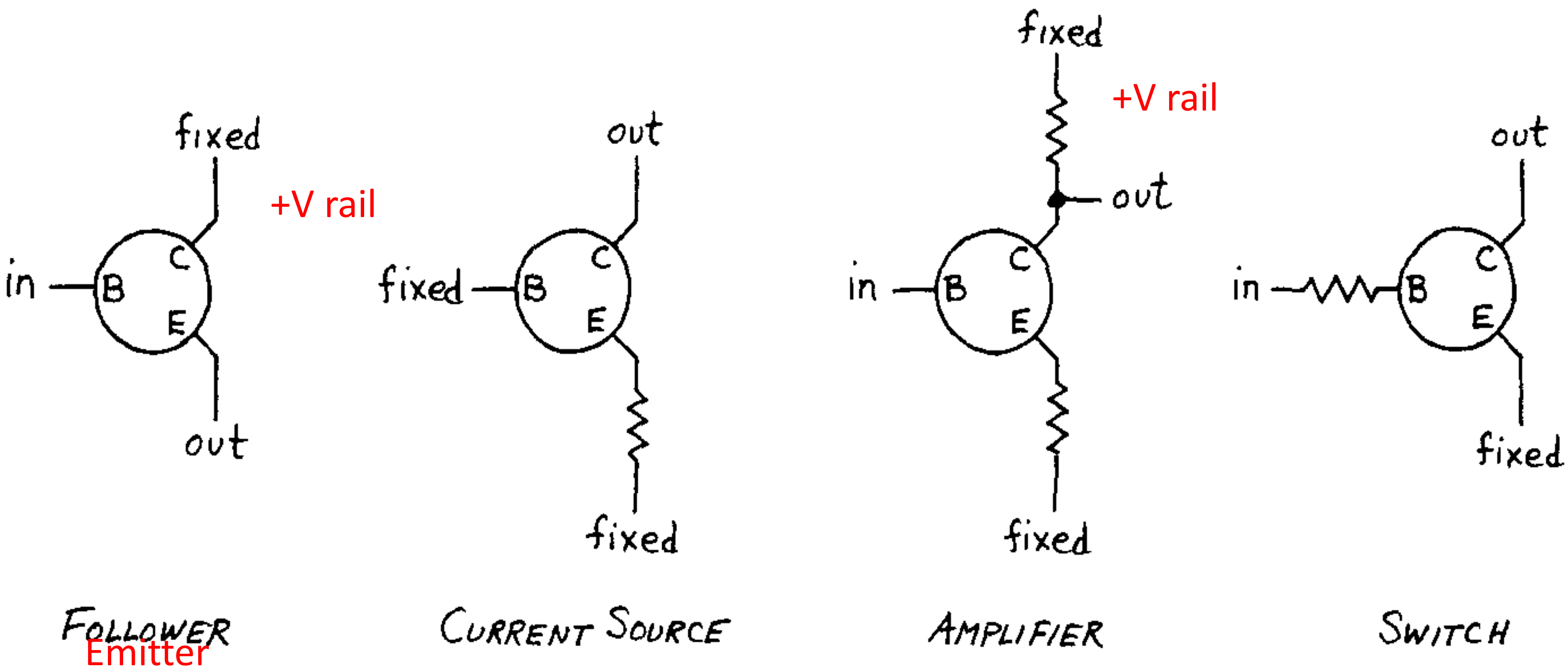
see Worked Exs. & assimilate pp 93 p90-3, 115-6

Next Monday's "must" reading:

Differential amps, FET's (field effect transistors): H&H 124-162

Your transistor circuits...

recognized by where you take your output, where V fixed



Common Emitter

Impedance Matcher

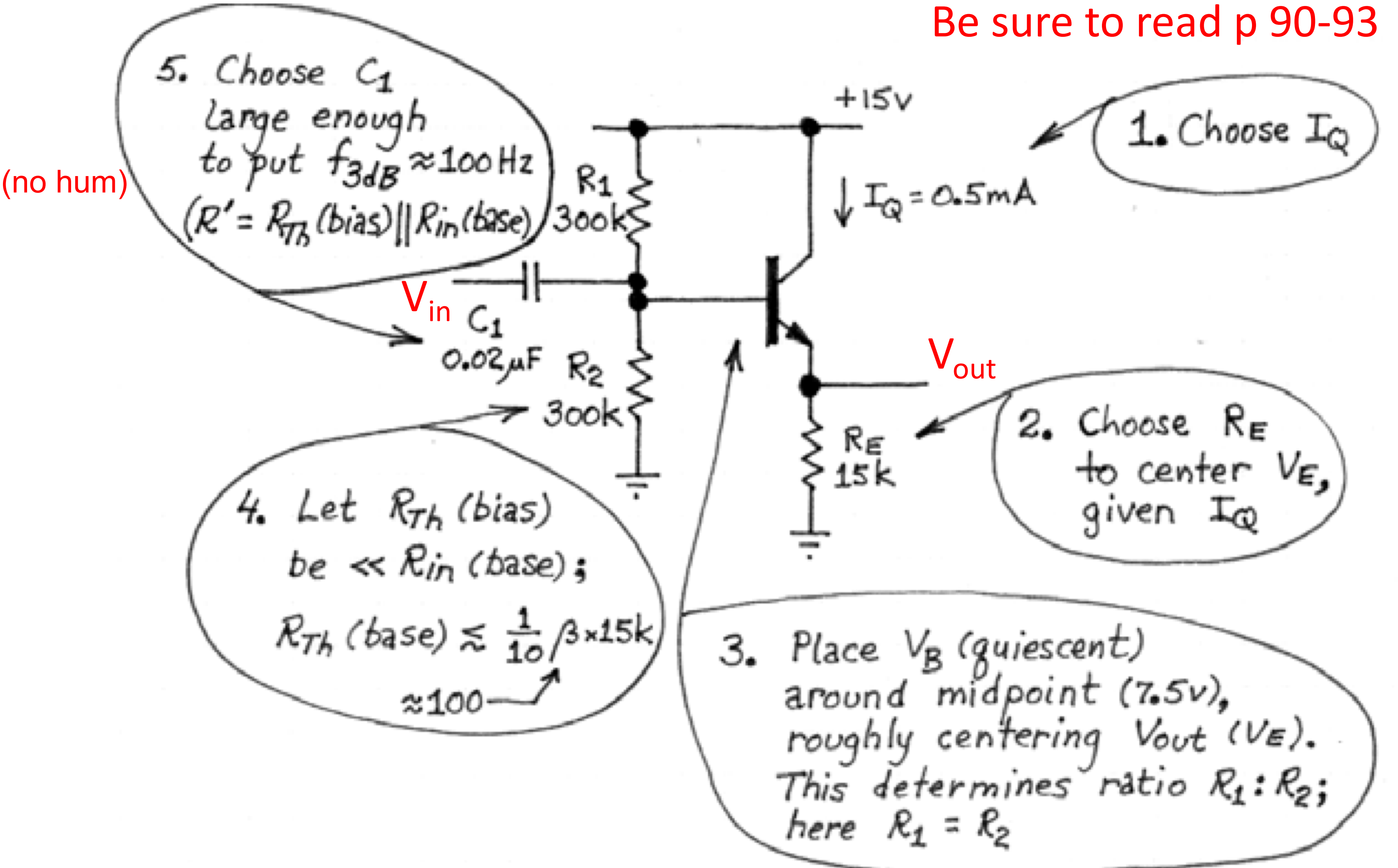
Current Amp

Voltage Amp

Steps in designing a transistor current amp ≡ impedance matcher

...the simplest is EMITTER FOLLOWER (non-inverting *i* amp):

Be sure to read p 90-93



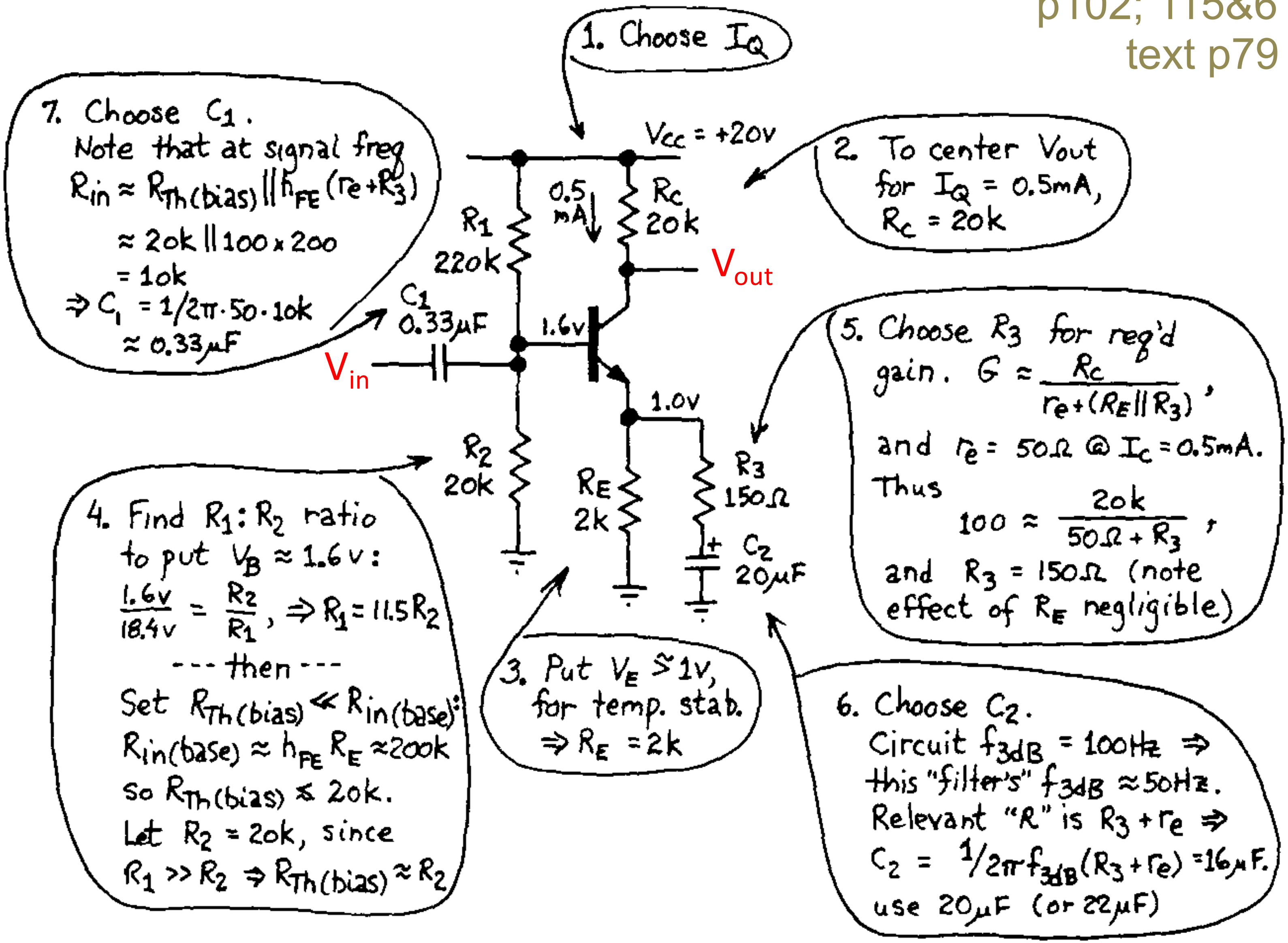
...but temp stability? touch it! linearity? low gain

Design COMMON EMITTER amp: temp stability & hi AC gain, ~100:

DC Gain = - R_C / R_E, nice! Bypass R_E to get AC gain > f_{3dB}~100 Hz (no hum).

Intrinsic, dynamic r_e, diode-like = 25Ω/I_C(mA). I_C quiescent = 0.5 mA

p102; 115&6
text p79



What to remember from Week 2?

Ratios: dB = 10 $\log_{10}$ (P_{out}/P_{in}) = 20 $\log_{10}$(V_{out}/V_{in}) ..."2" since P = V^2/R

20 dB = x10 V ratio

6 dB = x 2 V ratio

3 dB = x0.707 V ratio = ($1/\sqrt{2}$) = ½ power point

Frequency domain (radians) $\omega_{3dB} = 2\pi f = 1/\tau$ p39

vs time domain (Hz) $f_{3dB} = \omega_{3dB}/2\pi$ p40

Filters

RC τ = RC time constant for V_{out}/V_{in} to get to 0.63 of asymptote

~kΩ × μfd = millisec (ms) = "audio" frequencies 10Hz-20k

Rolloff response: 6dB/octave (20dB/decade) = x2 V drop per x2 freq, or 10×10

see Bode Plot

Hi (frequency) pass C = ac HF short, "bypasses" ac p41

Low f pass C = smoothing, "blocks" dc

3dB = down x2 in power (& 45° phase shift)

(Coils are a complement: Inductance $\tau = L/R$

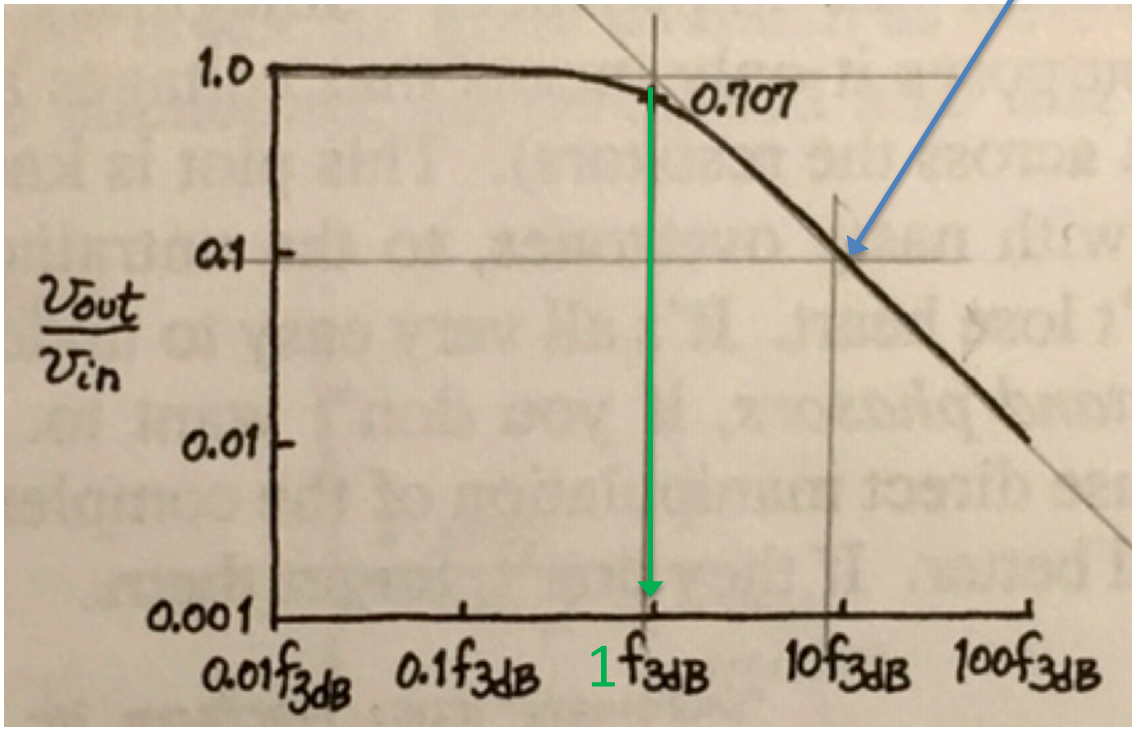
C + L give resonance: Tank (resonant) circuit $\omega = 1/\sqrt{LC}$)

Bode frequency roll-off plot for a low-pass filter:

6 dB/octave = 20 dB/decade = -1 log-log slope

x2 for 2 x10 for 10 straight line

p41



RC filters – time domain *vs* frequency domain L/R ~same

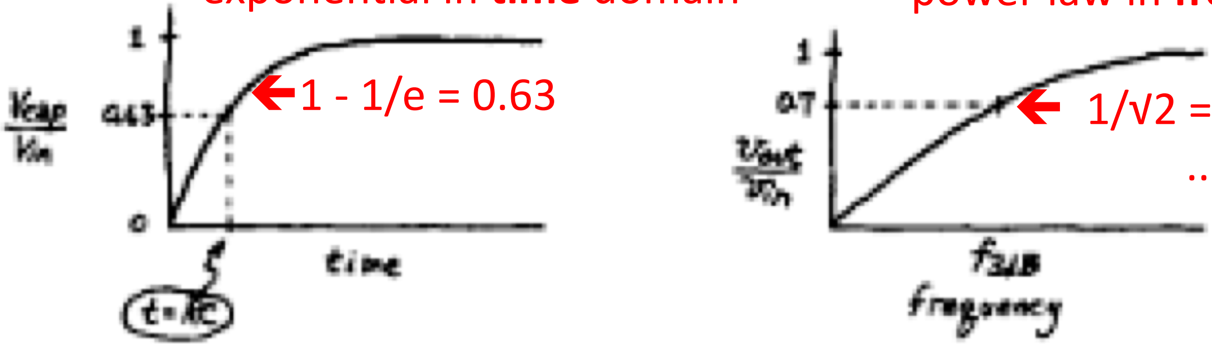
3 dB (0.707=1/√2) inflection point for V_o/V_i

vs. 6 dB/octave (x2 for x2 in frequency) = 20 dB/decade rolloff in f

x2 for 2 x10 for 10 p39

Do not confuse these *frequency-domain* pictures with the earlier *RC* step-response picture, (which speaks in the *time-domain*).

exponential in **time** domain power law in **frequency** domain



1/√2 = 0.707 in Volts ratio

...1/2 in Power ratio

Figure N2.16: Deceptive similarity between shapes of time- and frequency- plots of *RC* circuits

Not only do the curves look vaguely similar. To make things worse, details here seem tailor-made to deceive you:

- *Step response*: in the *time RC* (time-constant), V_{cap} moves to about 0.6 of the applied step voltage (this is 1 – 1/e).
- *Frequency domain*: at f_{3dB}, a frequency determined by *RC*, the filter's V_{out}/V_{in} is about 0.7 (this is 1/√2)

Default scope etiquette…
ask for tutorial if at all in doubt

V_{in} to channel 1, zero at +2 vertical boxes

V_{out} to channel 2, zero at -2 vertical boxes

Causality ⇒ trigger on input

Horizontal trace starts at horizontal box 1 to see precursors

Choose time scale to display a couple of cycles not too many, not too few

Trigger: normal, rising slope ~ never use "line" or "auto"

DC coupling...except to see DC offset

AC inserts a capacitor in the way

"Thou shall not touch trigger once its operational!!!"

"Only use 'Auto' in desperation to find the trace."

Use a x10 probe if you need to minimize disturbance to circuit.

Compensate the probe adjusting its capacitance using a square wave; it's Fourier transform has all frequencies.