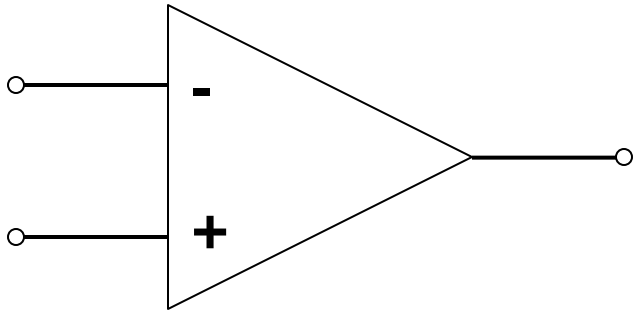
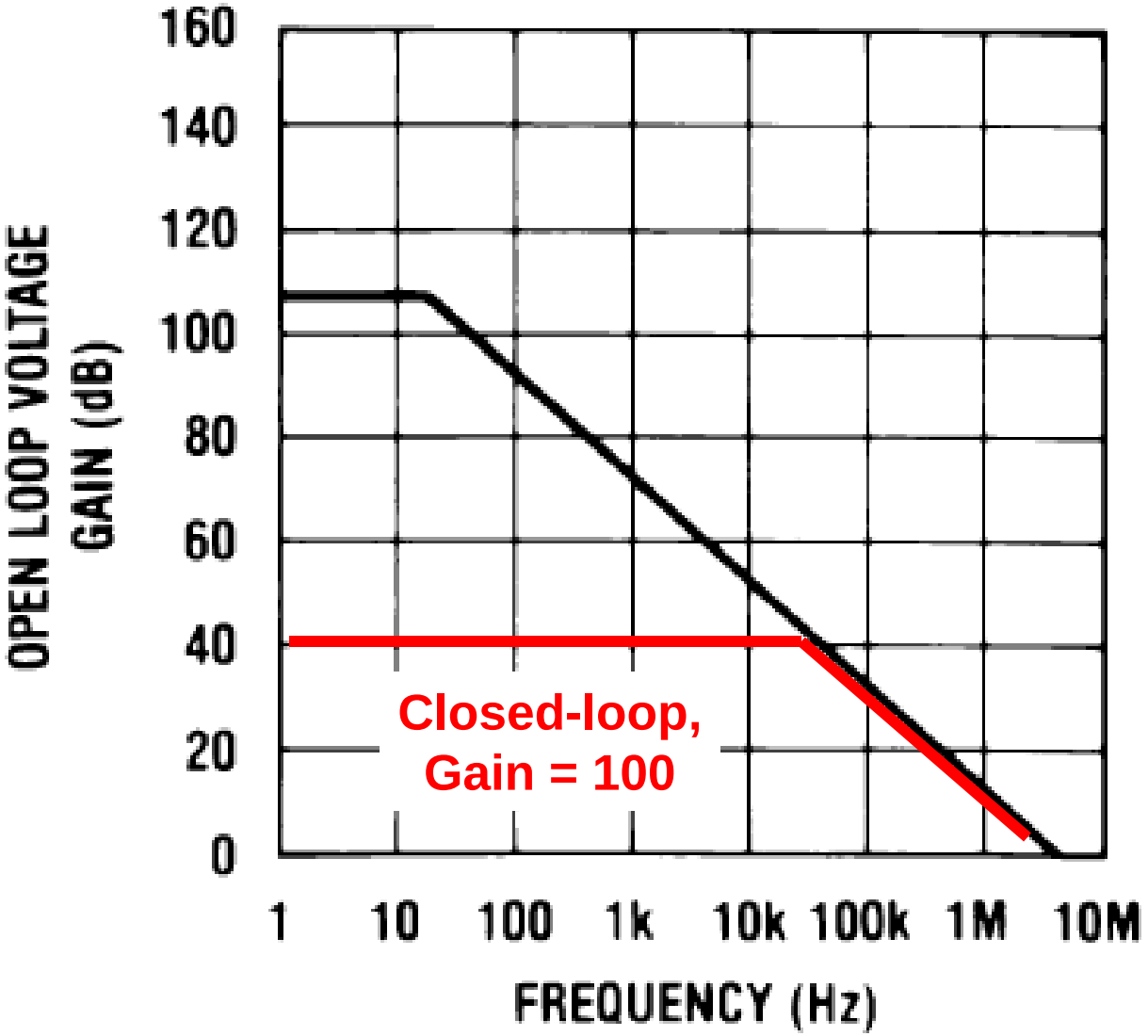


Ideal op-amp has the following characteristics:

1. Input impedance = infinity
2. Output impedance = 0
3. Voltage gain = infinity
4. Common-mode voltage gain = 0
5. V_{out} = 0 when both inputs are at the same voltage (i.e. zero “offset voltage”)
6. Output can change instantaneously (infinite slew rate)

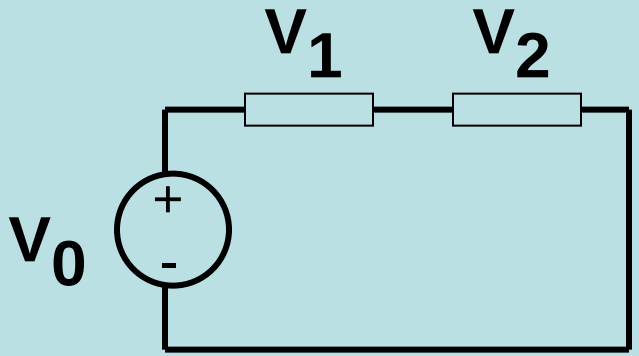
Open-loop gain for LF411



Electronics Review

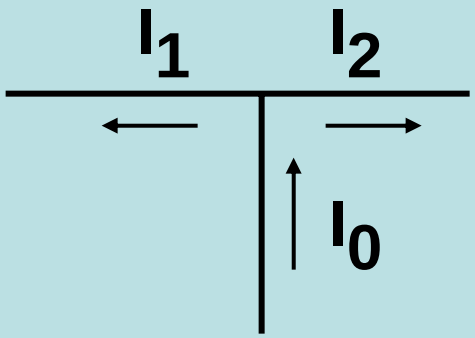
Kirchhoff's Laws

Energy is conserved



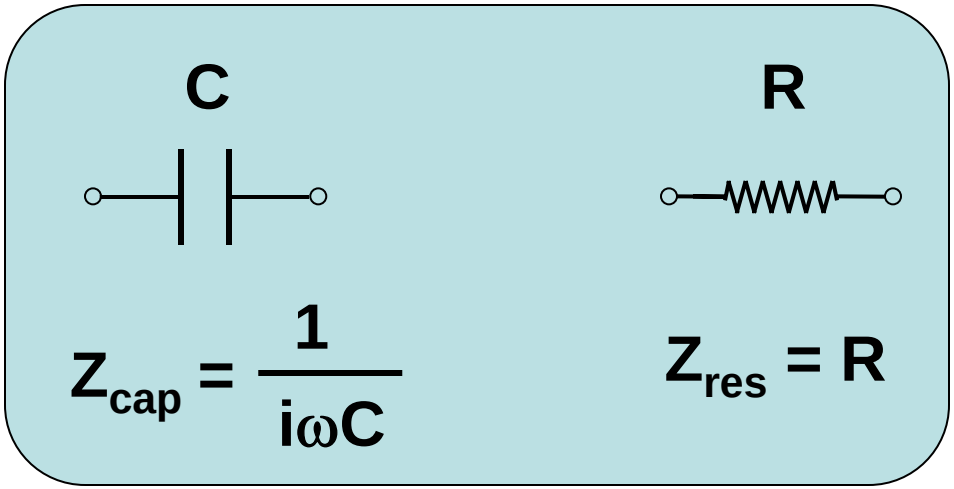
$$V_0 + V_1 + V_2 = 0$$

Charge is conserved



$$I_0 = I_1 + I_2$$

Impedances Model

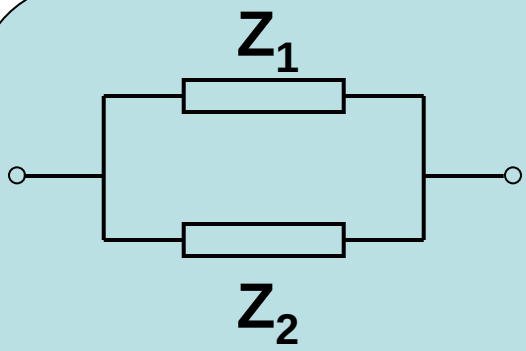


Differential Equation -> Algebraic Equation -> Impedance Model

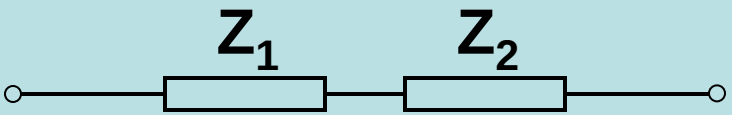
$e^{i\omega t}$ is an eigenvector of $\frac{d}{dt}$

Substitute $V = V_o e^{i\omega t}$, $I = I_o e^{i\omega t}$ into element relations $V = iR$, $i = C\frac{dv}{dt}$

Impedances behave like resistors

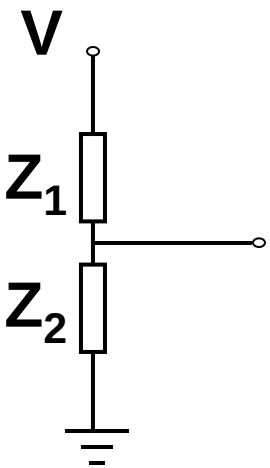


$$Z_{parallel} = \frac{Z_1 Z_2}{Z_1 + Z_2}$$



$$Z_{series} = Z_1 + Z_2$$

The Divider:

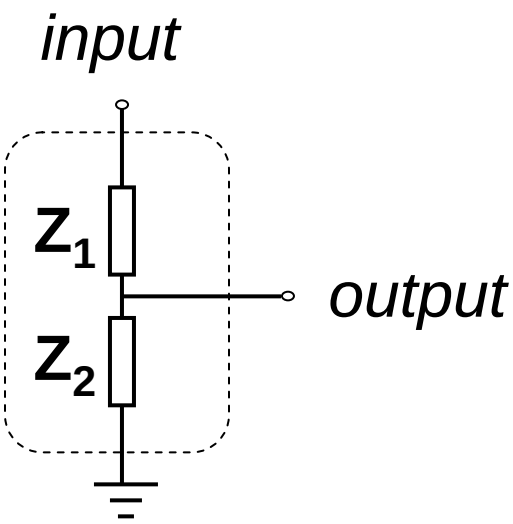


$$V_{out} = V \frac{Z_2}{Z_1 + Z_2}$$

Input and Output Impedances

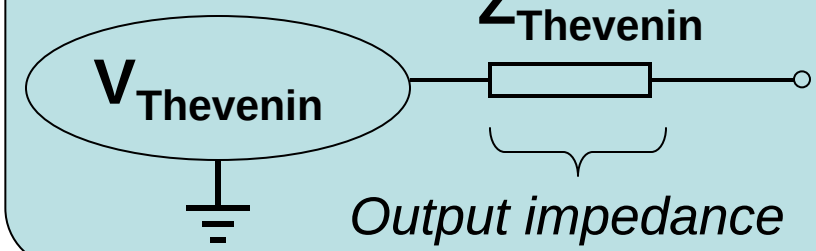
(Z_{output} of Stage 1) << (Z_{input} of Stage 2)

Example:



Input impedance: $Z_{input} = Z_1 + Z_2$

Output impedance: $Z_{output} = \frac{Z_1 Z_2}{Z_1 + Z_2}$

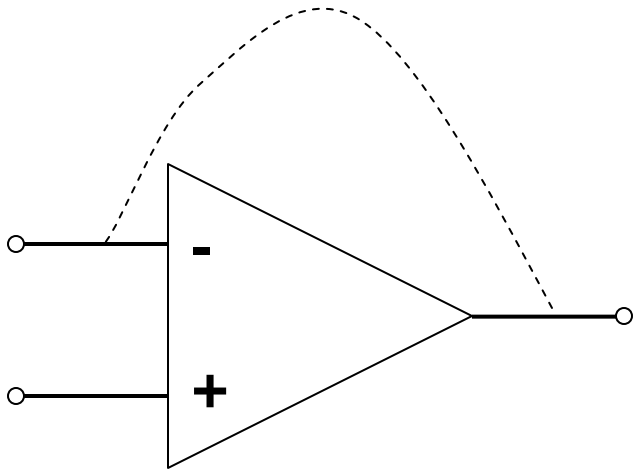


V_{thev} = Open circuit output voltage

Z_{thev} = Open circuit resistance

(V_{source}=short; i_{source}=open)

Op-Amps



Two golden rules:

1. No current flows in
2. Output does whatever it takes to make $V^+ = V^-$

Nearest Neighbor (NN) model for nucleic acids

Assumes that the stability of a given base pair depends on the identity and orientation of neighboring base pairs.

There are 10 NN dimer duplexes:

Sequence	ΔG_{37° (kcal/mol) Unified (ref. 22)
AA/TT	−1.00
AT/TA	−0.88
TA/AT	−0.58
CA/GT	−1.45
GT/CA	−1.44
CT/GA	−1.28
GA/CT	−1.30
CG/GC	−2.17
GC/CG	−2.24
GG/CC	−1.84
Average	−1.42
Init. w/term. G·C*	0.98
Init. w/term. A·T*	1.03
Sodium concentration, M	1.0

Example:
5’-CA-3’ paired with **3’-GT-5’** is represented at **CA/GT**

SantaLucia, *PNAS* **95** 1998.

Nearest Neighbor (NN) model for nucleic acids

Total free energy,

Free energy from 10 possible NN

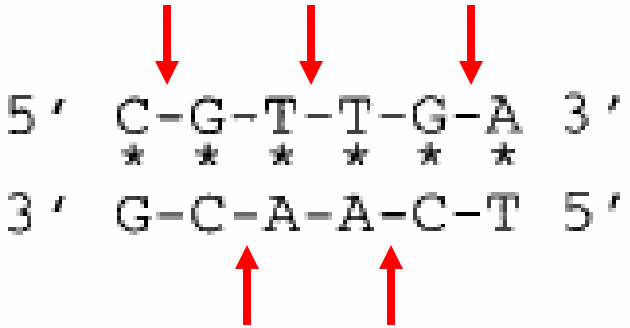
$$\Delta G^\circ(\text{total}) = \Sigma_i n_i \Delta G^\circ(i) + \Delta G^\circ(\text{init w/term G·C}) + \Delta G^\circ(\text{init w/term A·T})$$

Initiation parameters (terminal GC or AC)

Initiation parameters account for sequence independent effects (e.g. terminal/internal NNs and counterion condensation)

SantaLucia, *PNAS* **95** 1998.

Biochemistry: SantaLucia



$$\Delta G^\circ_{37}(\text{pred.}) = \Delta G^\circ(\text{CG/GC}) + \Delta G^\circ(\text{GT/CA}) + \Delta G^\circ(\text{TT/AA})$$

$$+ \Delta G^\circ(\text{TG/AC}) + \Delta G^\circ(\text{GA/CT}) + \Delta G^\circ(\text{init.})$$

$$= -2.17 - 1.44 - 1.00 - 1.45 - 1.30 + 0.98 + 1.03$$

$$\Delta G^\circ_{37}(\text{pred.}) = -5.35 \text{ kcal/mol}$$

$$\Delta G^\circ_{37}(\text{obs.}) = -5.20 \text{ kcal/mol}$$

FIG. 1. Application of the unified nearest neighbor parameters (Table 1) and Eq. 1 to predict ΔG°_{37}. Each arrow points to the middle of one of the NN dimers. The duplex CGTTGA·TCAACG is non-self-complementary and thus $\Delta G^\circ(\text{sym})$ is zero.

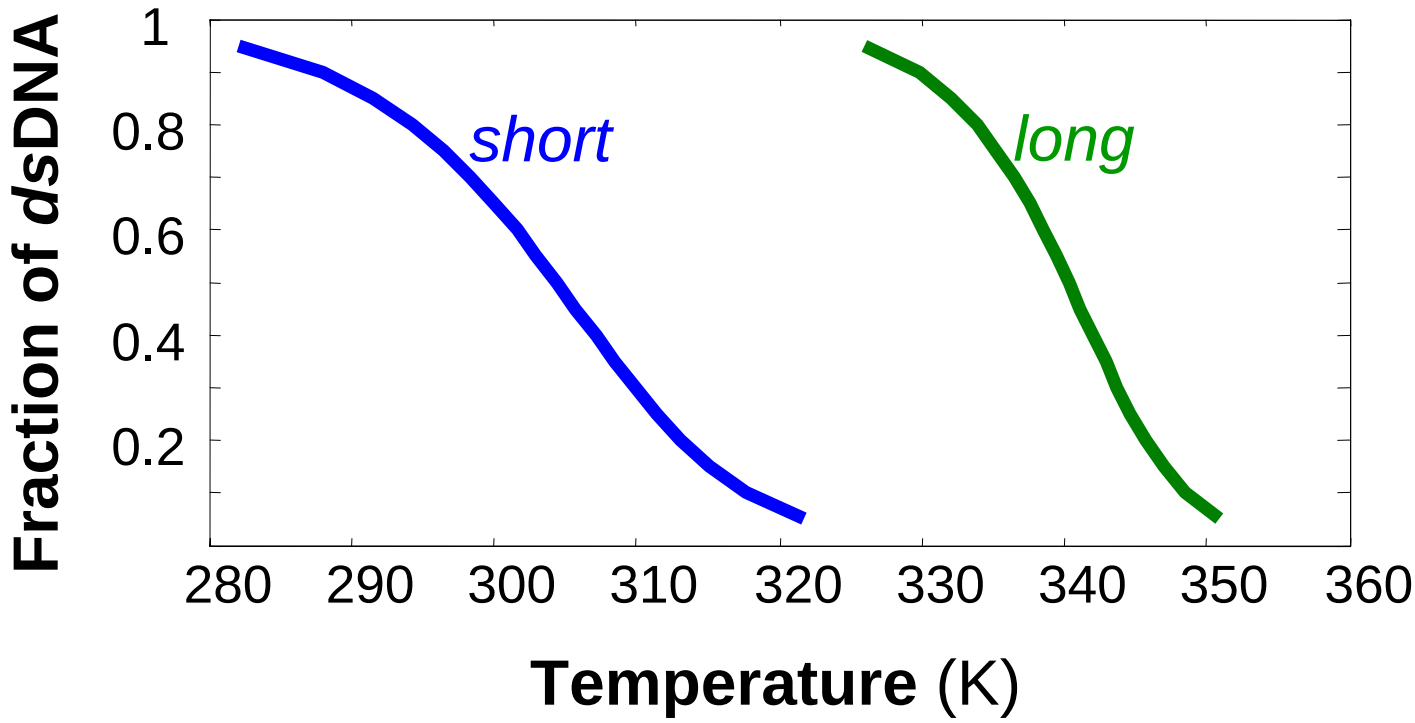
SantaLucia, *PNAS* **95** 1998.

Table 2. Unified oligonucleotide $\Delta H°$ and $\Delta S°$ NN parameters in 1 M NaCl (22)

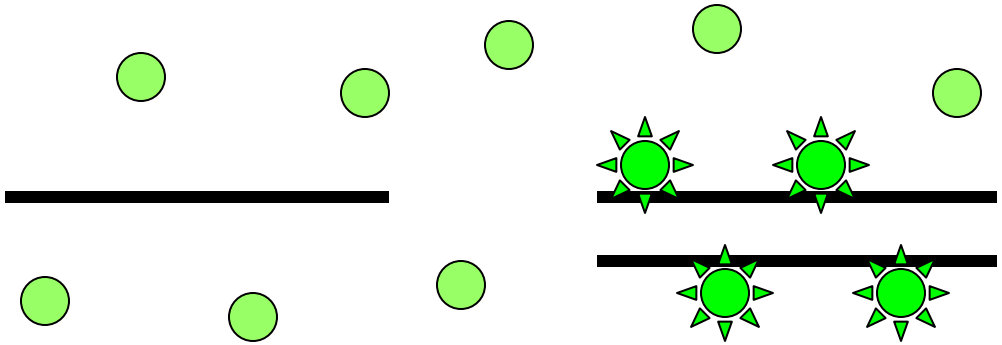
Sequence	$\Delta H°$ kcal/mol	$\Delta S°$ cal/k·mol
AA/TT	−7.9	−22.2
AT/TA	−7.2	−20.4
TA/AT	−7.2	−21.3
CA/GT	−8.5	−22.7
GT/CA	−8.4	−22.4
CT/GA	−7.8	−21.0
GA/CT	−8.2	−22.2
CG/GC	−10.6	−27.2
GC/CG	−9.8	−24.4
GG/CC	−8.0	−19.9
Init. w/term. G·C	0.1	−2.8
Init. w/term. A·T	2.3	4.1
Symmetry correction	0	−1.4

SantaLucia, *PNAS* **95** 1998.

Oligomer	ΔH (kJ/mol)	ΔS (kJ/mol-K)
5’-ATAGC-3’ 3’-TATCG-5’	-169	-0.483
5’-ATAGCATAGC-3’ 3’-TATCGTATGC-5’	-336	-0.919



SYBR green



The fluorescence intensity of SYBR Green is enhanced over 100-fold on binding to DNA which results in bright fluorescent DNA bands against a very dark background

Using a transilluminator, it is possible to detect less than 100 pg of SYBR Green-stained DNA by eye and tens of picograms using a CCD system.

20.309 Experimental Setup