AC analysis of switched-capacitor networks

Method: Separate simulation and combination of both switching phases

Principle: Combination of two separate blocks with cross-coupled controlled current sources.

Example: See Fig. 1 (S/C integrator).

Current i_{A2} (right amplifier) controls the corresponding current source in the left amplifier. Corresponding cross-coupling for the other 3 currents.

Each switched capacitor is replaced by a parallel combination of a current source and a resistor. The resistor value is determined by the sampling frequency and the capacitor value (see example below).

Both output signals u_{A1} and u_{A2} are to be added.

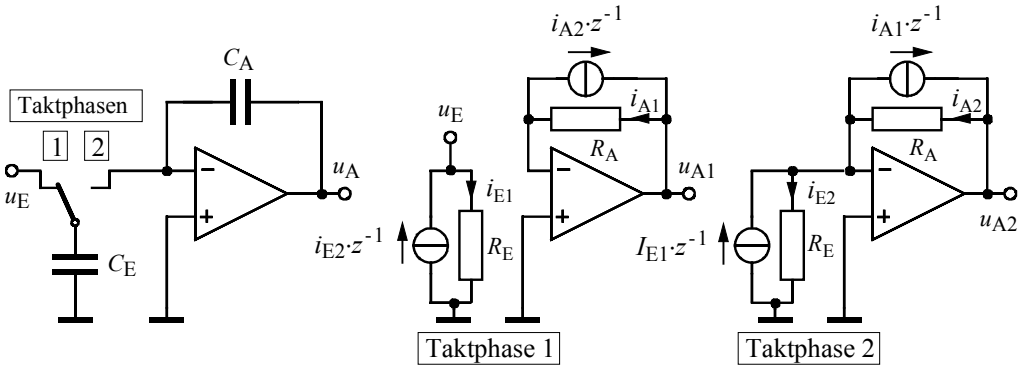

Fig. 1 SC-Integrator (Superposition of both output voltages u_{A1} and u_{A2})

Example: Classical *RC-Miller*-Integrator: R_1=10 kΩ, C_2=15,9 nF (τ=159 µs, f_0=1/(2πτ)=1 kHz);

- SC-Äquivalent (Fig. 1, left): Sampling period T_A=10 µs, $C_E=T_A/R_1$=1 nF, $C_A=C_2$=15,9 nF;
- For simulation (Fig. 1, right) $R_E=T_A/C_E$=10 kΩ, $R_A=T_A/C_A$=628,3 Ω, z^{-1}=exp(-jωT_A);

Remark:
Most simulation programs contain controlled sources allowing *Laplace* notation $s=j\omega$ and z^{-1}=exp(-s·1E-5).
For correct determination of the current direction for all currents i_E und i_A it is recommended to use in addition zero-voltage sources in series to R_E and R_A ,correspondingly.
Perform an ac analysis (input node u_E). Both output voltages u_{A1} and u_{A2} are added and the transfer function u_A/u_E can be displayed, as shown in Fig. 2.

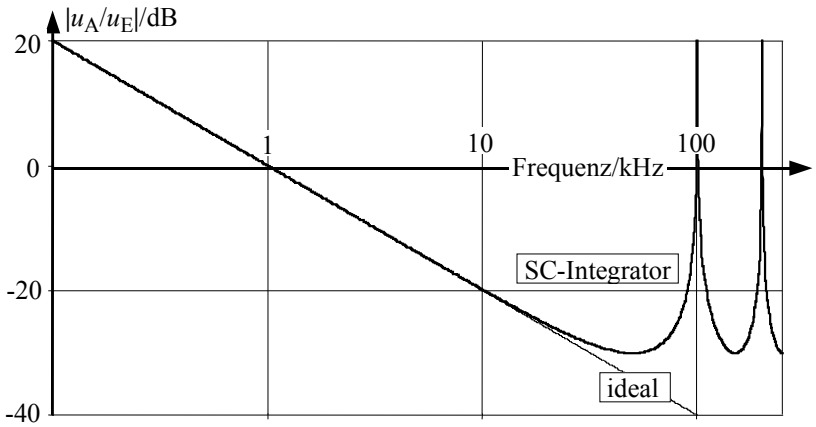

Fig. 2 Transfer function: SC-Structure (Fig. 1), and for comparison: Ideal integration.

Remark: In practice, the output of S/C stages resembles a sample-and-hold function – leading to a drastical improvement of the integrator function for all frequencies above 10 kHz.