# Systematic Generation of Transconductance Based Variable Gain Amplifier Topologies

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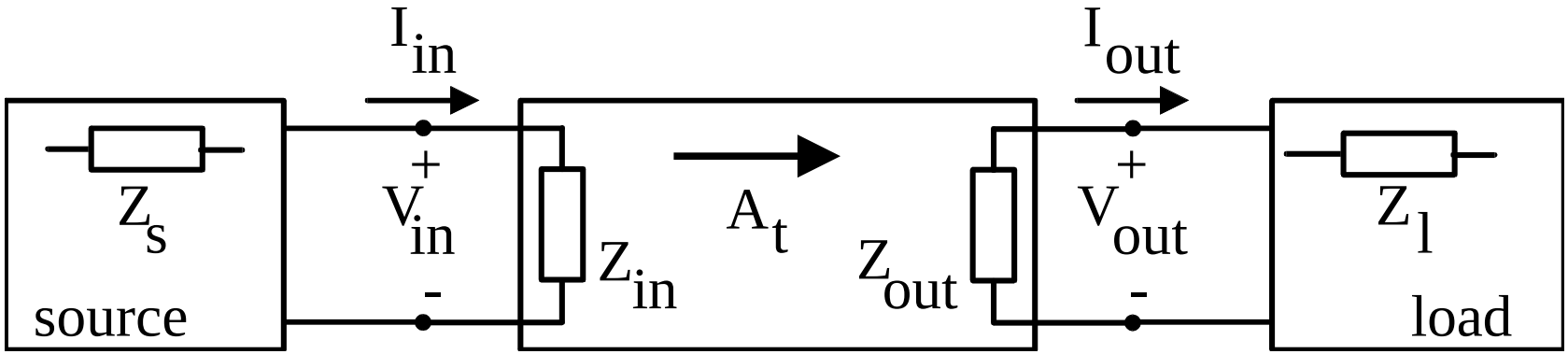
# Introduction on Linear Circuit Building Blocks

**Linear blocks with V-V, I-I, I-V, V-I function are often used!**

**(e.g. Voltage/Current/Transimpedance Amplifiers, Gm-C filters)**

**Model: linear two-port connected between source and load.**

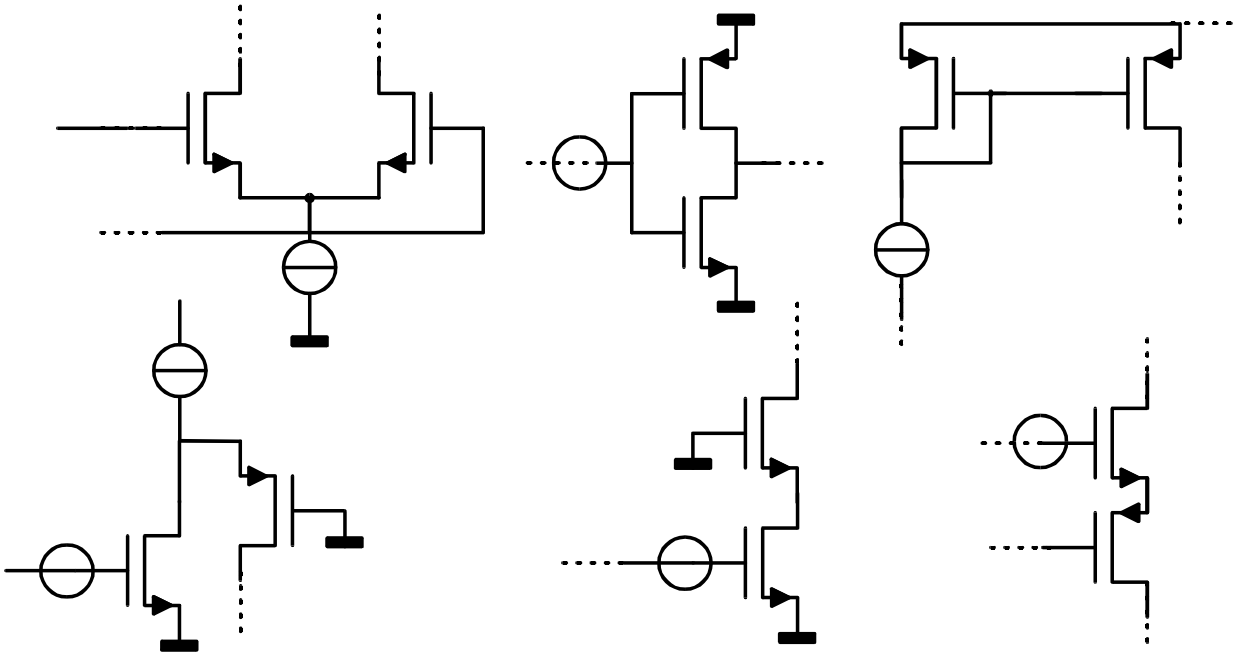



**Wanted:**

- $Z_{in}$, $Z_{out}$: $\infty \vee 0 \vee Z_{exact}$ : => 3 x 3 “basic blocks”.
- Transfer function: accurate or electronically controllable

**Question: How to Design Linear Building Bocks in CMOS?**

# A Design Philosophy for Linear MOS Circuits



**Frequently used building blocks**

**Problem**:
Huge number of topologies
=> designer uses experience & intuition!!

**But**:

- Overlooking options!
- If fail, then??

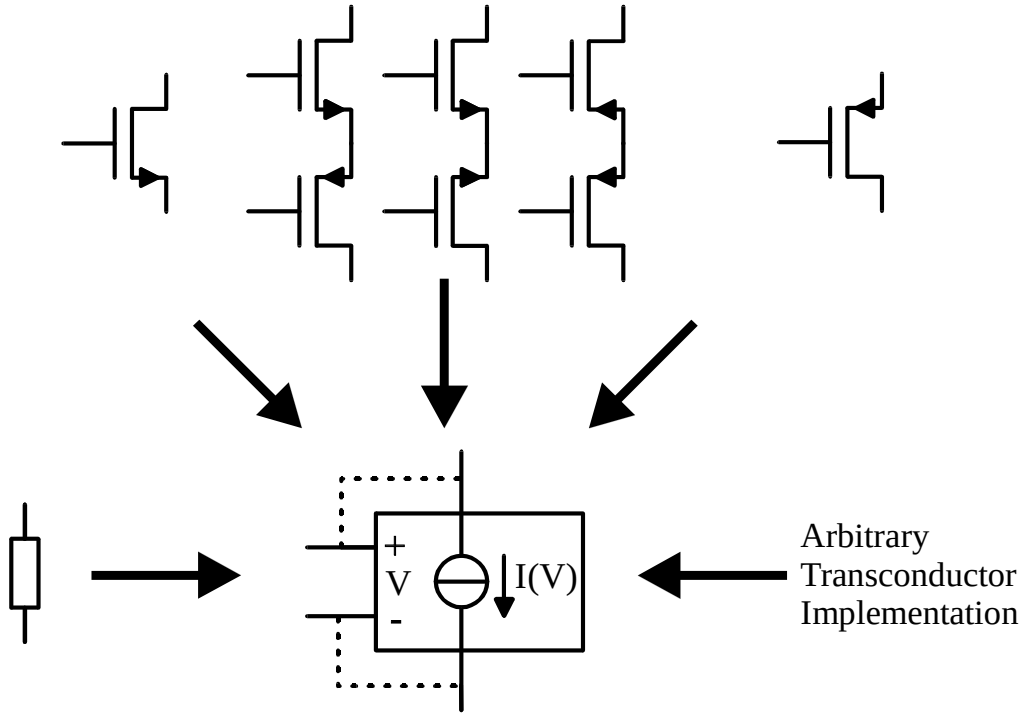
***Aim: Systematic Approach!!***
***Basic Assumptions???***

**Clues:**

- ***"Simple is beautiful"*** **<=>** ***HF, low noise, low current***
- ***Transconductance Based*** **<=>** ***HF, matching, electronic control***

# VCCS as Unifying Element for Topology Generation

- **Abstraction: *Voltage Controlled Current Source (VCCS)*.**
- **Use VCCS as unifying Element to *reduce number of topologies*.**

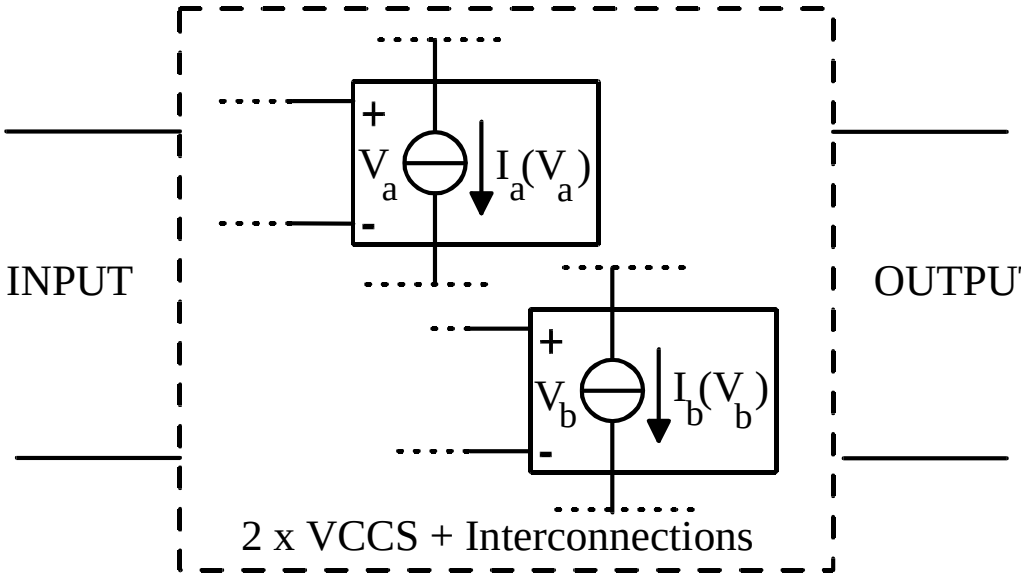



VCCS covers:

- MOST or MOST-pair (No bias shown!!)
- Resistor
- Arbitrary Transconductor (larger circuit, BJT, JFET)

**Systematic Generation of *ALL SIMPLE* Topologies with V*CCSs*!**

# Systematic Generation of All Simple VCCS Topologies

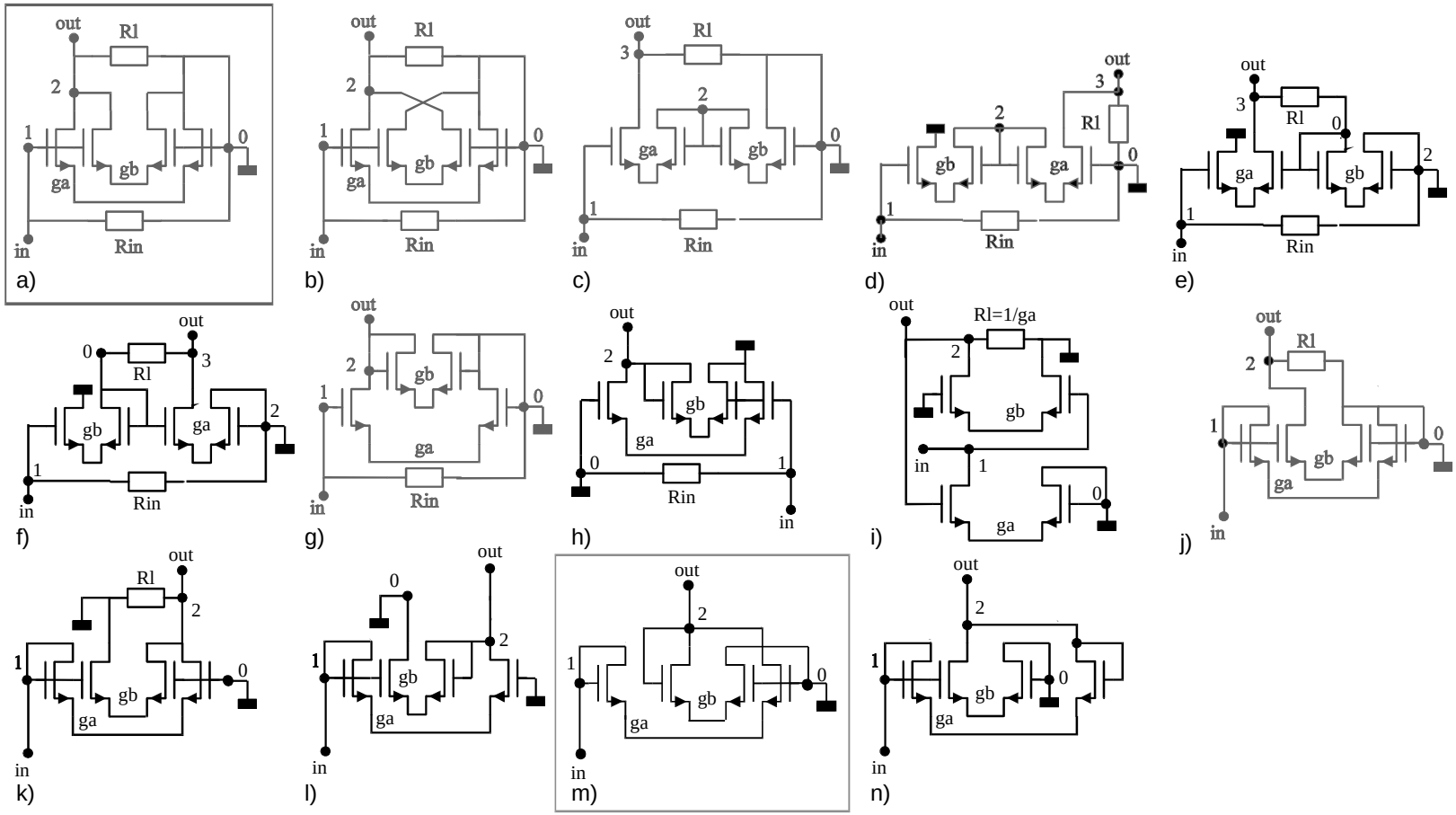



- How Simple?????
  1 VCCS => only V-I and I-V;
  2 needed for V-V and I-I!!
- MAPLE Program: Generate all 2VCCS topologies (graphs).
- Symbolic Analysis Program: select useful cases (non-zero).

**Results:**

- 145 topologies*(Number of VCCS implementations) => ***A LOT!***
- ***Transconductances*** determine ***port impedances*** and ***transfer functions***
- ***All 3x3 useful types*** of buildings block covered directly or approximated

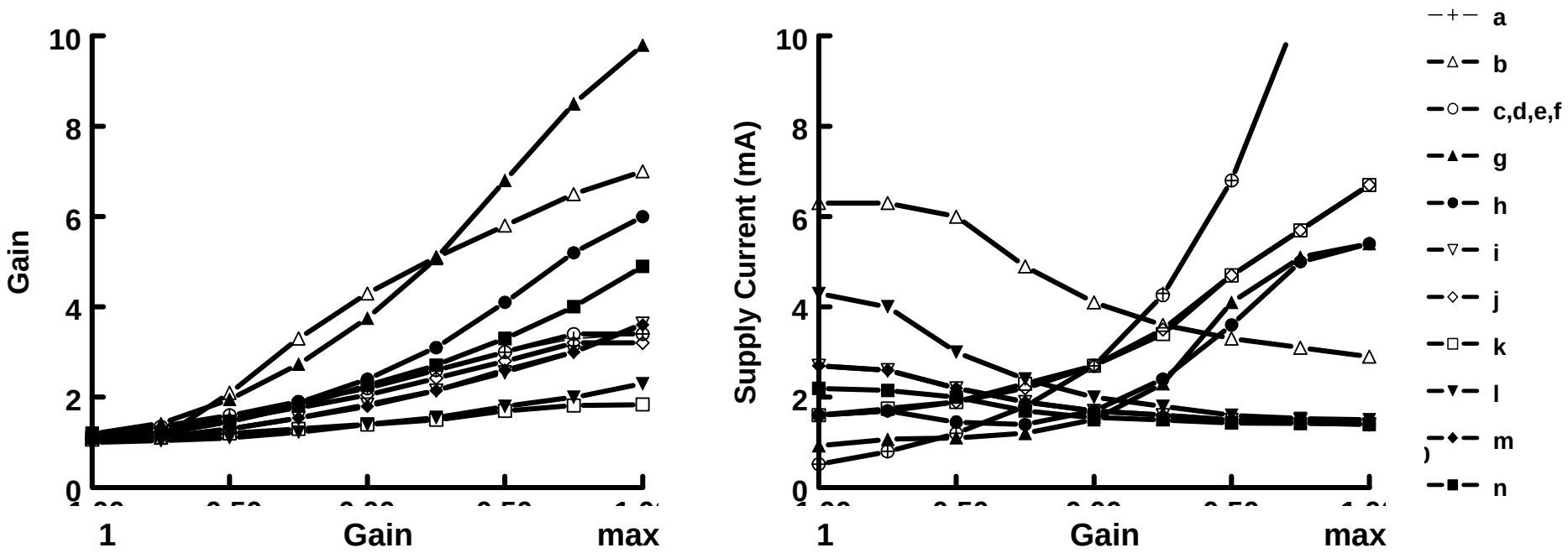
# APPLICATION: Variable Gain Amplifiers with $Z_{in}=R_{in}$




- First AGC Stage after SAW filter.
- $R_{in}$ needed for filter termination.
- Compare topologies => Equal Diff. Pairs (omit bias)

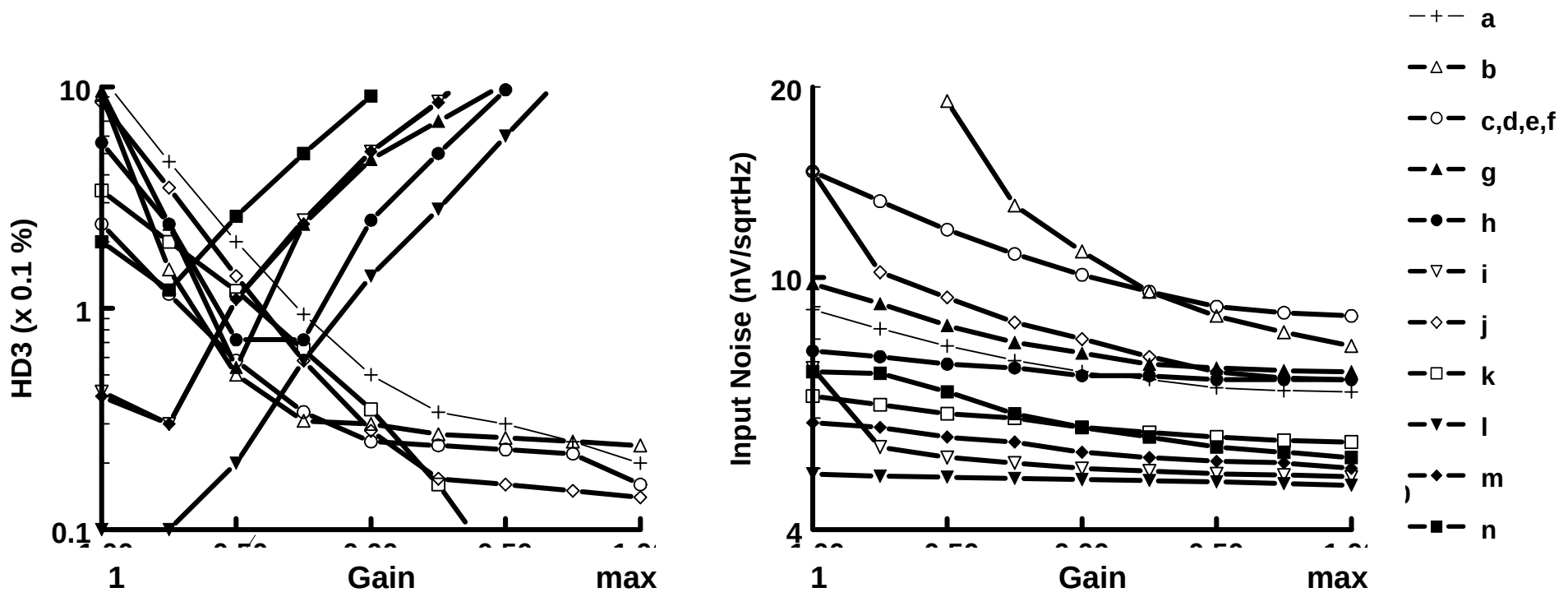
**_= Known to me. Do you know the others? Would you conceive ALL?**

# Performance Comparison for Equal Normalised VCCSs




- **Normalised VCCS: differential pair tuning range: $G_m$=0.5-2mS (W/L=150/1.5; Tail bias current 0.25..5 mA, $V_{GS}$-$V_{TN}$ = 0.1-1V).**
- **All equal minimum gain of 1; scale nominal VCCS if needed.**
- **Gain: 1→2, but also 1→10; Supply current: 0.5mA...10 mA**

# Distortion and Noise




- ***Significantly differences*** **in values and trends** ***due to topology***
- **Various mixes of + and - => *alternative topologies useful!!***

# Conclusions

**Design Philosophy for Linear Circuit building blocks:**

- ***Generate All Simple Transconductance Based Topologies!!***
- ***Use VCCS as Abstraction and Unifying Element to reduce number of topologies***

**Example: Variable Gain Amplifiers with 2 VCCSs:**

- **14 basic topologies with very *significant differences* in performance with +/- points in *various mixes***

**=> *Alternative Topologies are Useful to Find Best Fitting!!!!***