Analog Design: Still Crazy After All These Years

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The Challenge to the Analog Designer

- The analog designer constantly is challenged with
  - Higher performance specifications
  - More complex chip designs
  - Technologies that provide smaller design rules but poorer quality transistors
- The analog designer relies more heavily on analog EDA tools with each new technology node

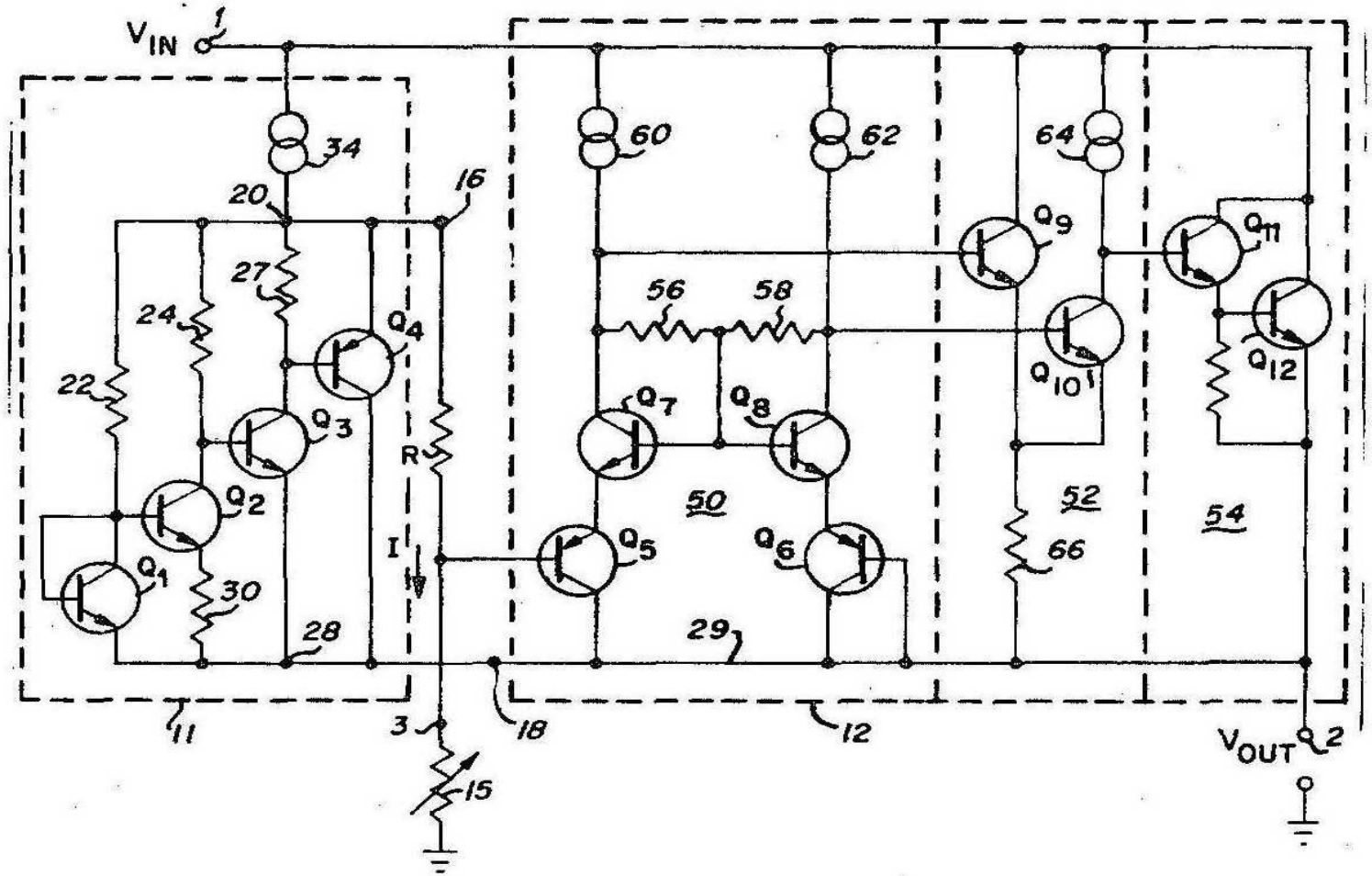
The Challenge to the Analog EDA Tool Developer

- The EDA Tool Developer is challenged with
  - Keeping up with the latest technology
  - Supporting all of the legacy technologies
  - Attempting to anticipate what designers will do and need next
- The only positive aspect is that computing technology is constantly improving

Ten Circuits That Had Profound Effects on Analog Simulation

- The Bandgap Reference (1964)
- The Switched-Mode Power Supply (1967)
- The Op Amp (1968)
- The Gilbert Multiplier (1968)
- The Phase-Locked Loop (1969)
- The DRAM (1970)
- The Switched Capacitor ADC (1978)
- The Delta-Sigma Modulator (1978)
- Dynamic Logic (1982)
- RF CMOS Circuits (1988)

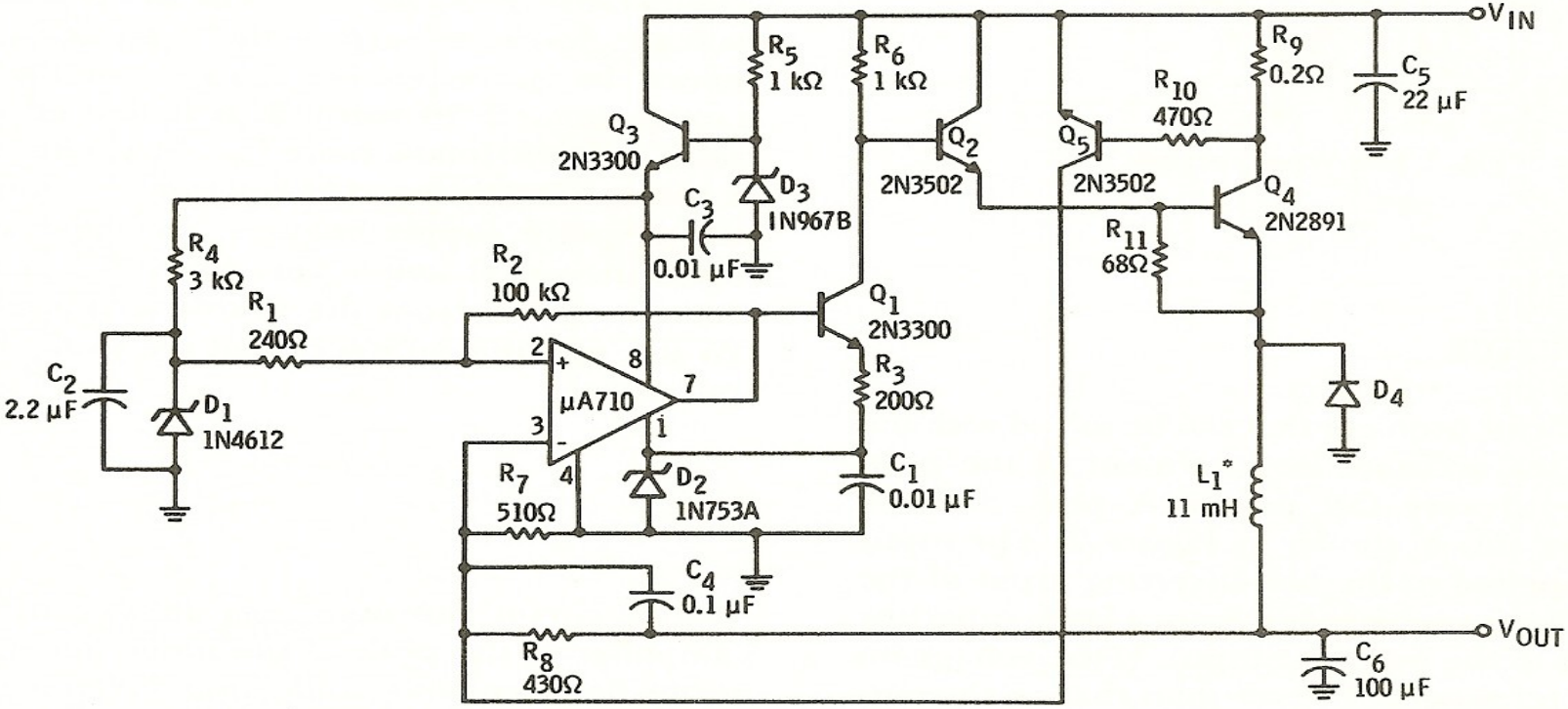
The Bandgap Reference (1964)



The Bandgap Reference (1964)

- The need to understand bias circuits for integrated circuits was the genesis of IC simulation tools at UC Berkeley (BIAS)
- Even with the simplest of models any but a first order analysis of circuits like the bandgap reference is intractable
- Thus was the BIAS program created!!!

The Switched-Mode Power Supply (1967)

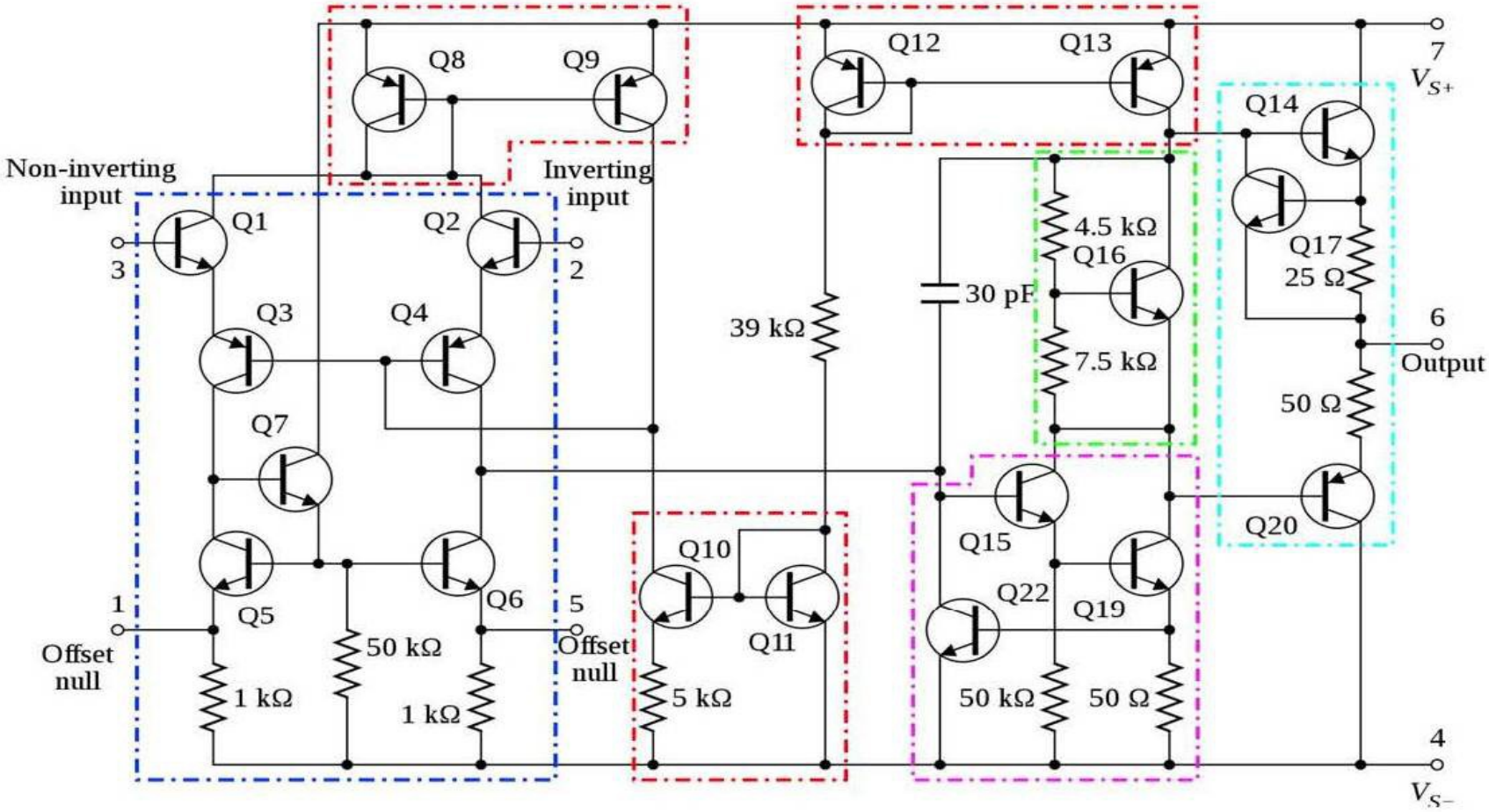


*250 turns #20 enameled copper wire wound on Molybdenum Permalloy Toroid (Arnold Engineering Co. #253168-2)

The Switched-Mode Power Supply (1967)

- Switched mode power supplies introduced the challenge of circuits with widely spaced time constants
- Proper simulation required implicit integration techniques
- Steady-state analysis techniques also were required to achieve reasonable computer execution times

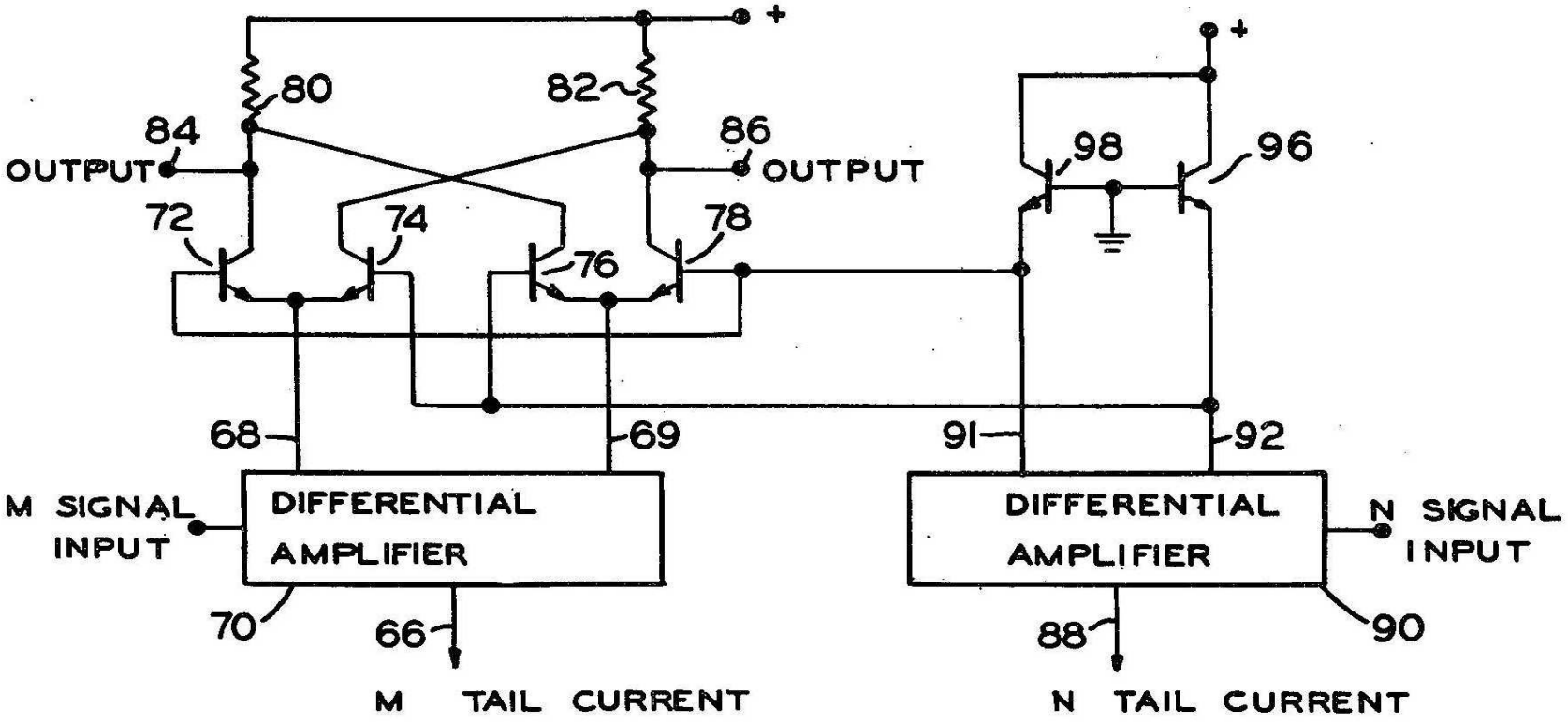
The Op Amp (uA741 - 1968)



The Op Amp (uA741 - 1968)

- With the Op Amp came the need to perform many different types of analysis
  - DC Operating Point Analysis (with sensitivity)
  - AC Small Signal Analysis
  - Transient Analysis
  - Noise Analysis
  - Distortion Analysis
- As Op Amps came into wide use, macromodeling became a common way of dealing with circuits containing many op amps

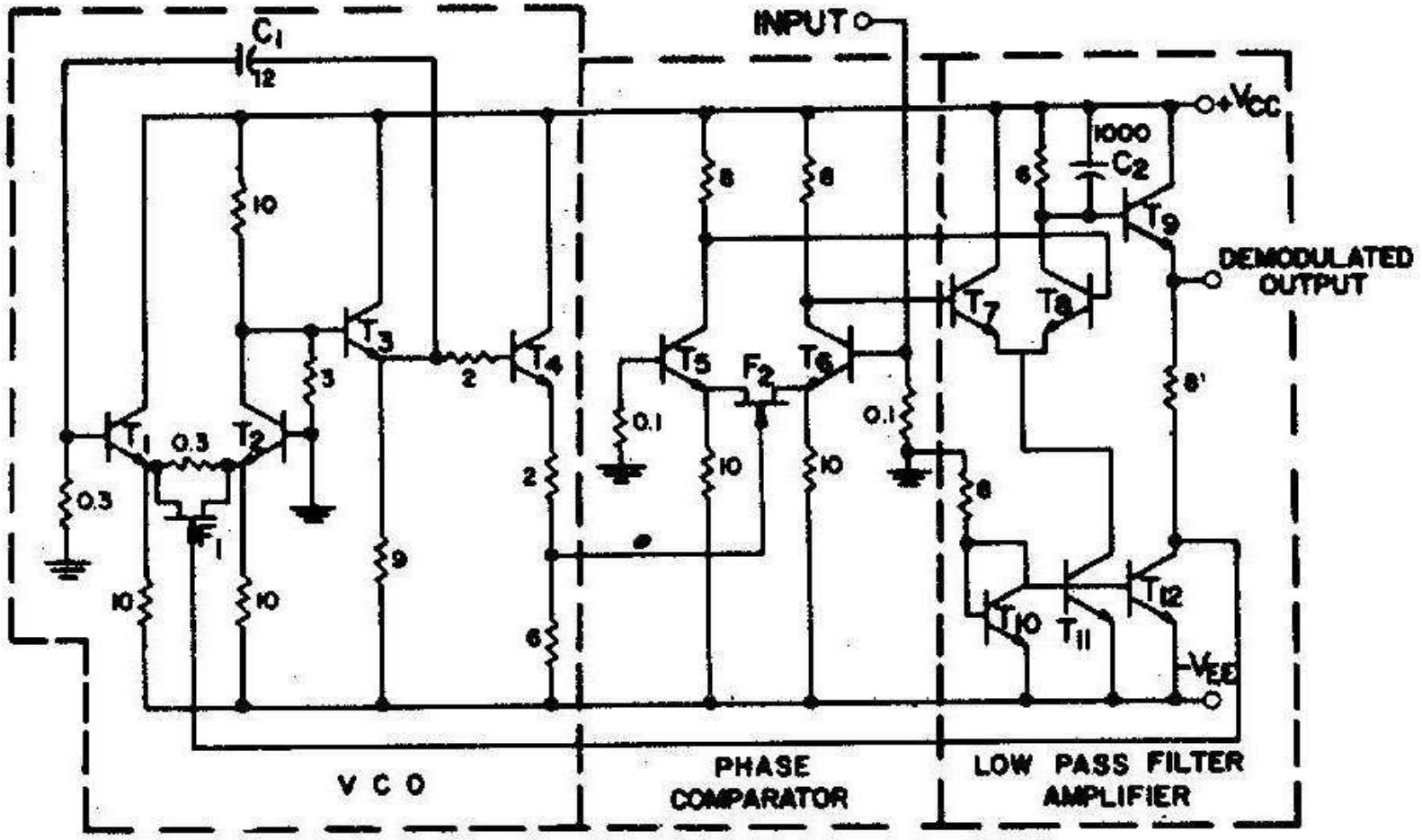
The Gilbert Multiplier (1968)



The Gilbert Multiplier (1968)

- The Gilbert Multiplier introduced many simulation challenges
  - Widely spaced time constants
  - Steady state analysis capability necessary
  - Simulation of mixer noise
  - Simulation of distortion
- It would be twenty years before these issues were adequately addressed

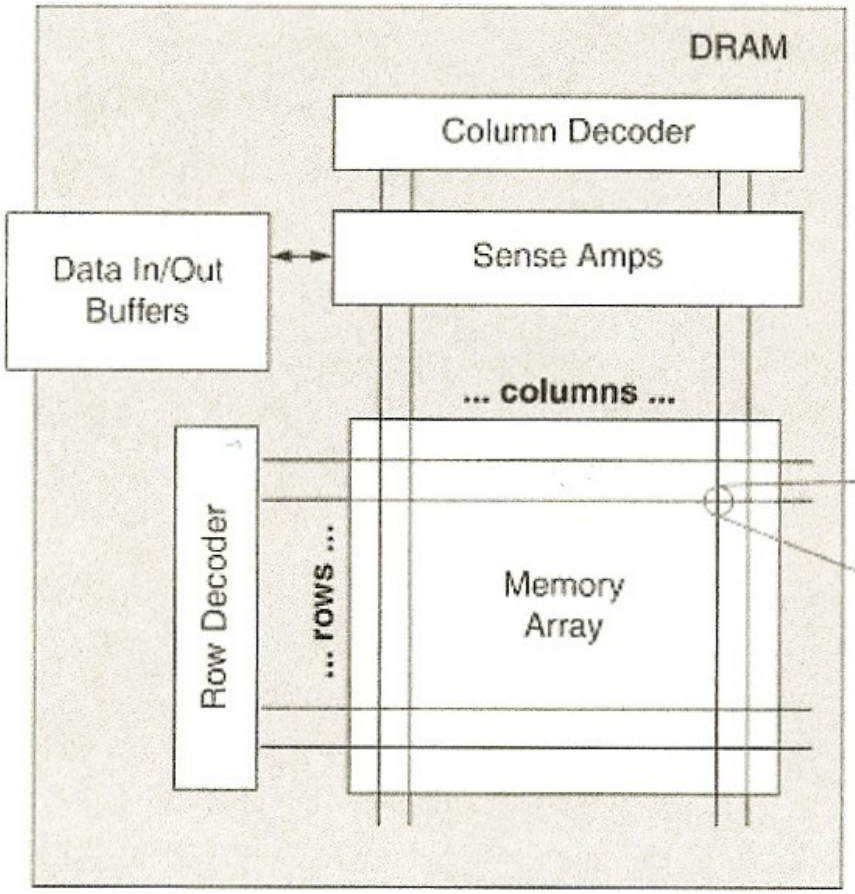
The Phase-Locked Loop (1969)

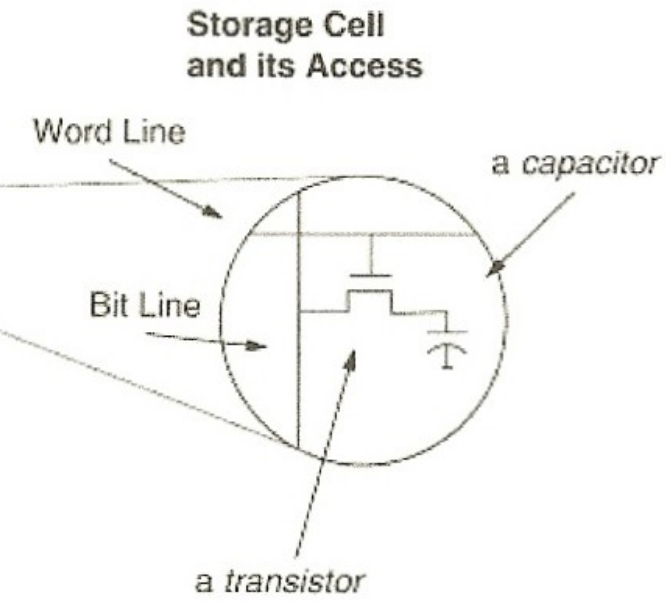


The Phase-Locked Loop (1969)

- The Signetics NE565 chip successfully introduced PLLs into many system designs
- However, simulating systems with PLLs was a challenge
  - Widely spaced time constants
  - Steady state analysis necessary
  - Simulation of jitter was a challenge
- Once again, it would be twenty years before these issues were adequately addressed

The DRAM (1970)

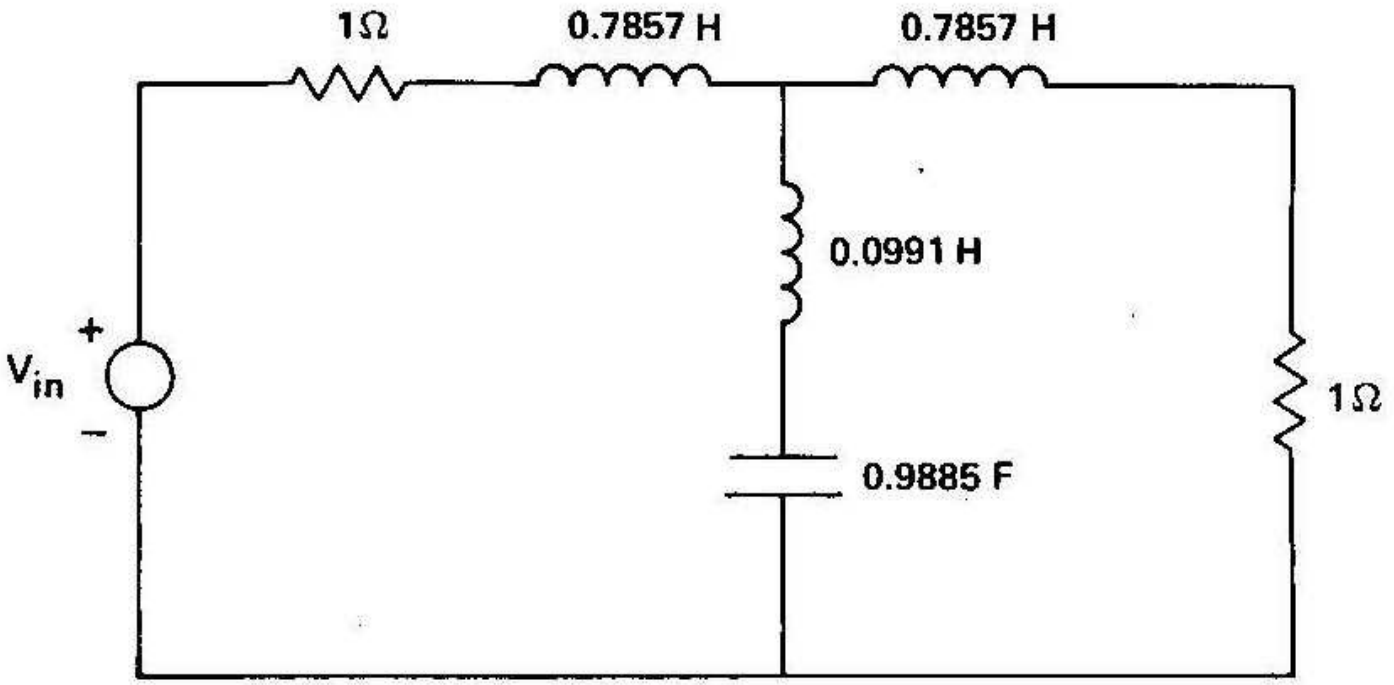




The DRAM (1970)

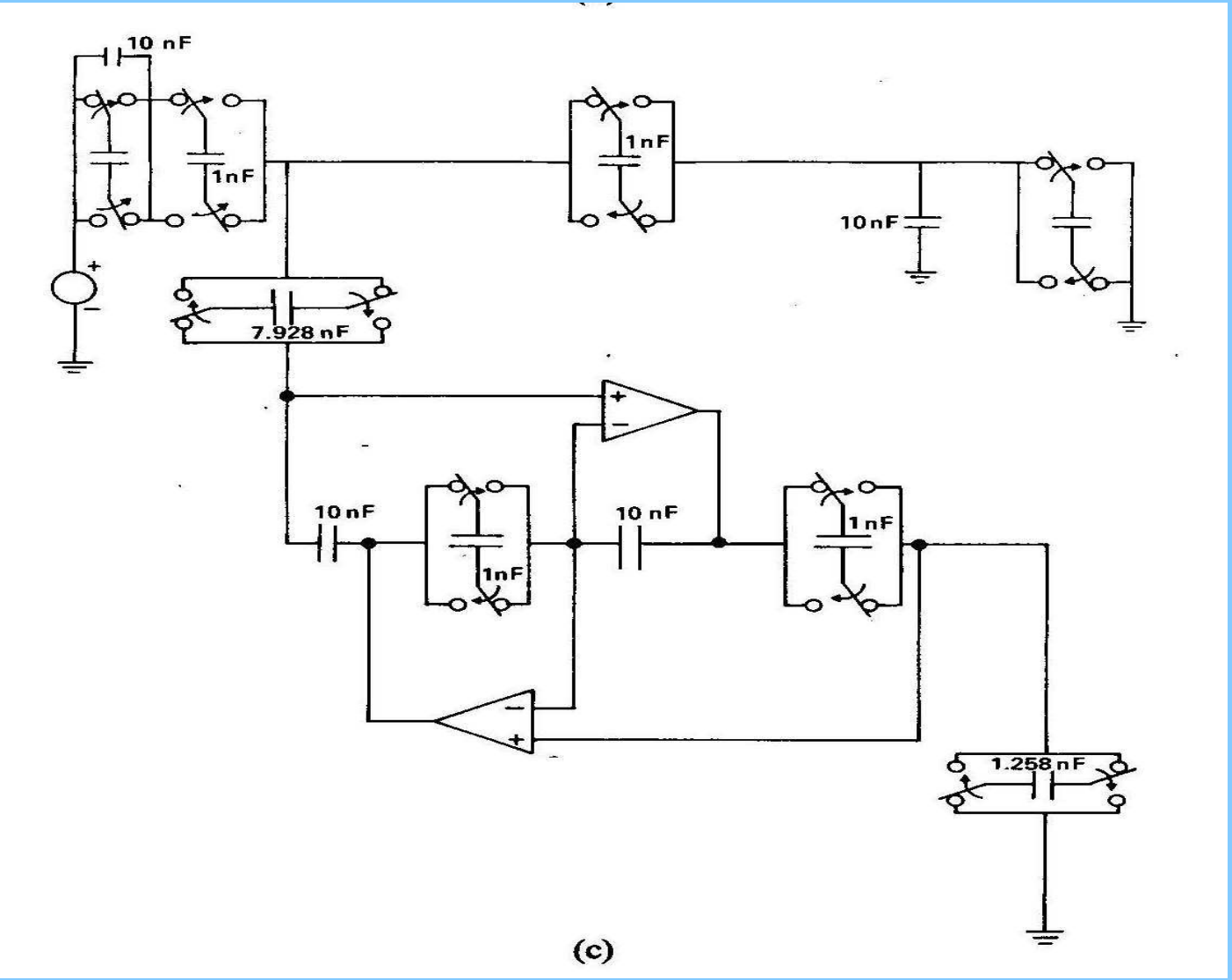
- Simulation of Dynamic Random Access Memories posed several other challenges
  - The circuit to be simulated was always large and usually gigantic
  - Device models required more accuracy than for digital logic, with careful attention to leakage
- However, straightforward transient analysis solved almost all of the DRAM simulation problems

Switched-Capacitor Filters (1978)



(a)

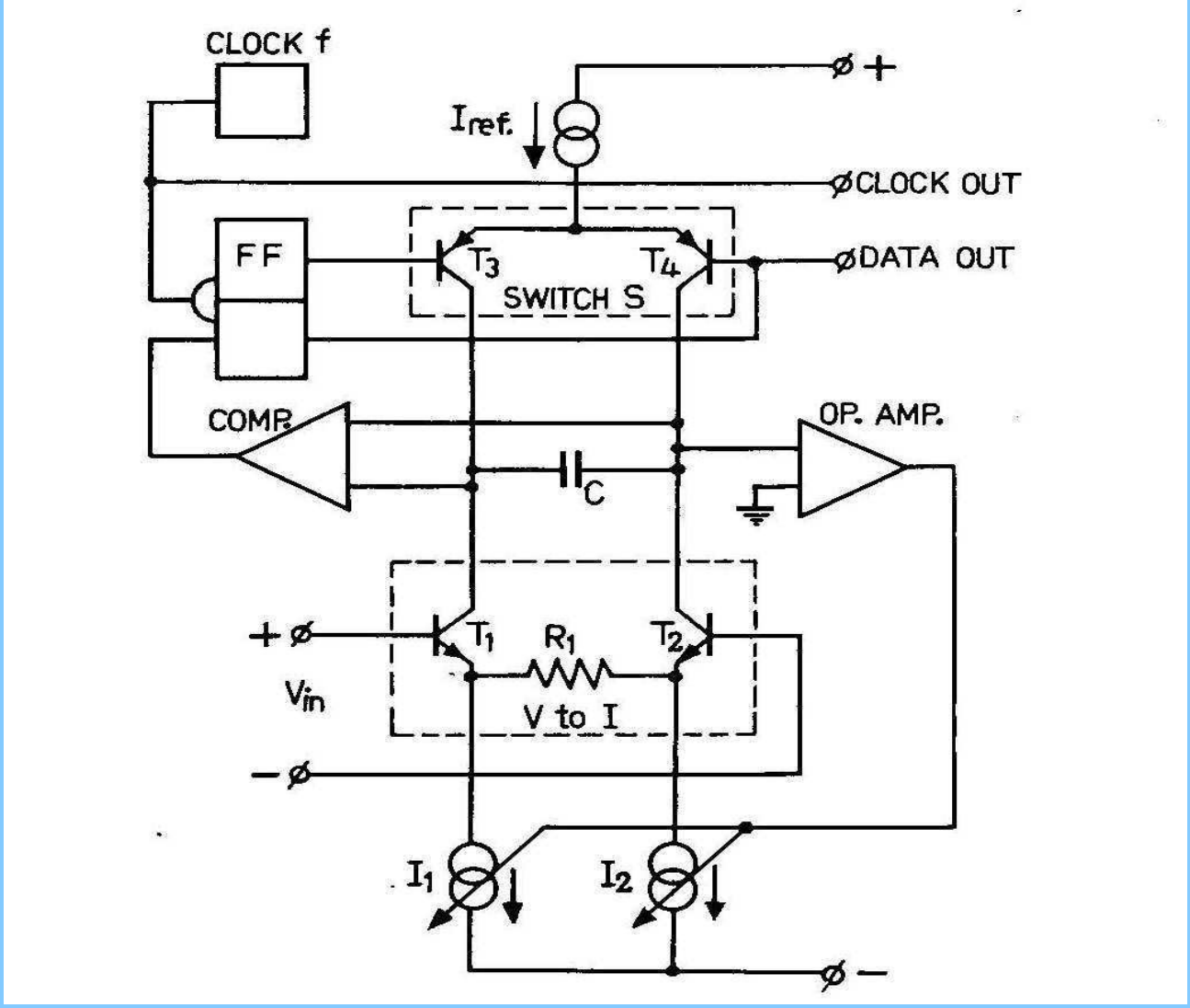
Switched-Capacitor Filters (1978)



Switched-Capacitor Filters (1978)

- Switched capacitor filters also presented simulation challenges
  - Widely spaced time constants
  - Steady state operation
  - Nonlinear frequency-domain analysis
  - Tough noise and distortion problems
- New programs, such as SWITCAP, were developed to overcome some of these problems

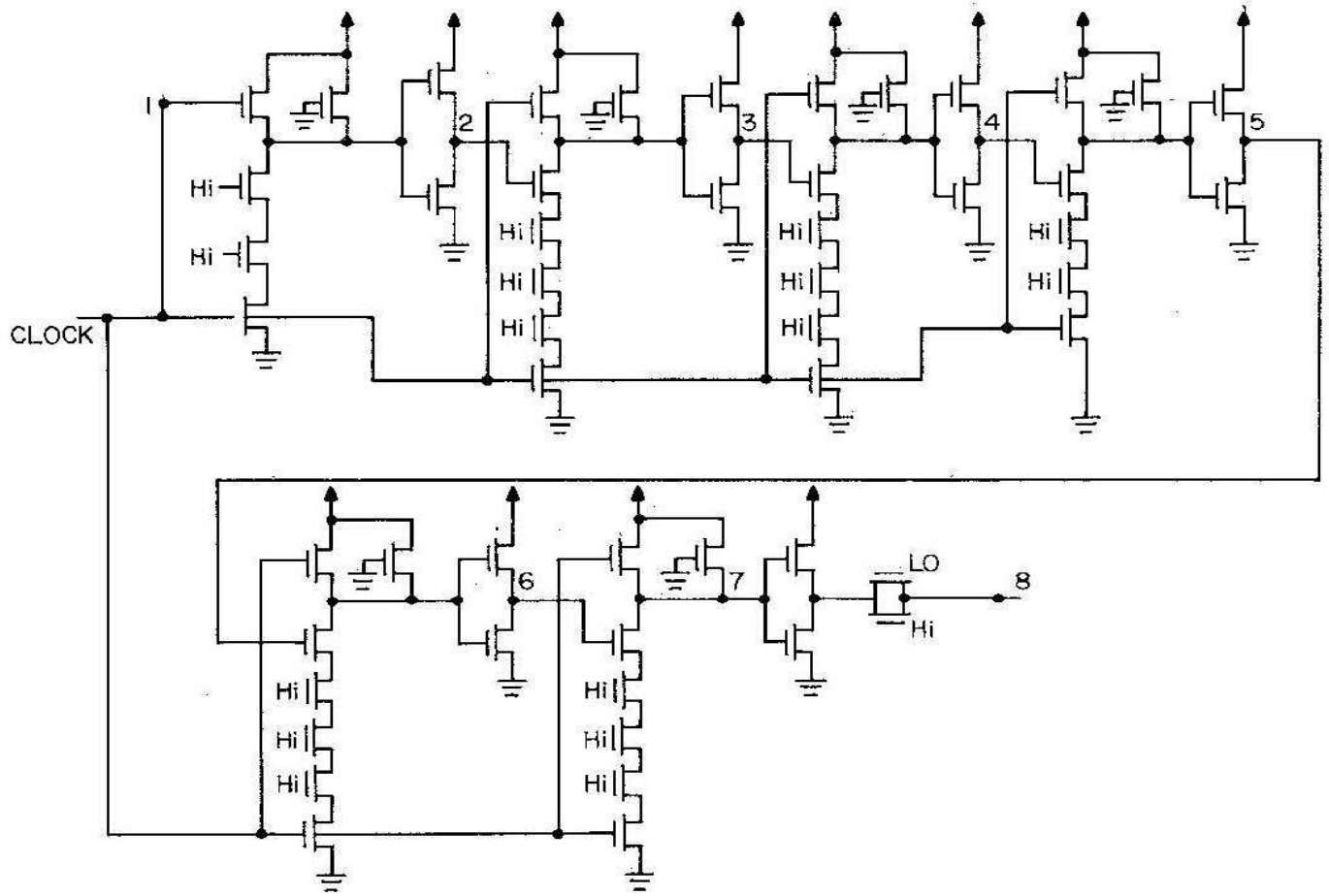
The Delta-Sigma Modulator (1978)



The Delta-Sigma Modulator (1978)

- The delta-sigma modulator provided a very efficient solution to the ADC problem and became widely adopted
- The simulation challenges with this class of circuit were so daunting that behavioral modeling became a widely adopted method

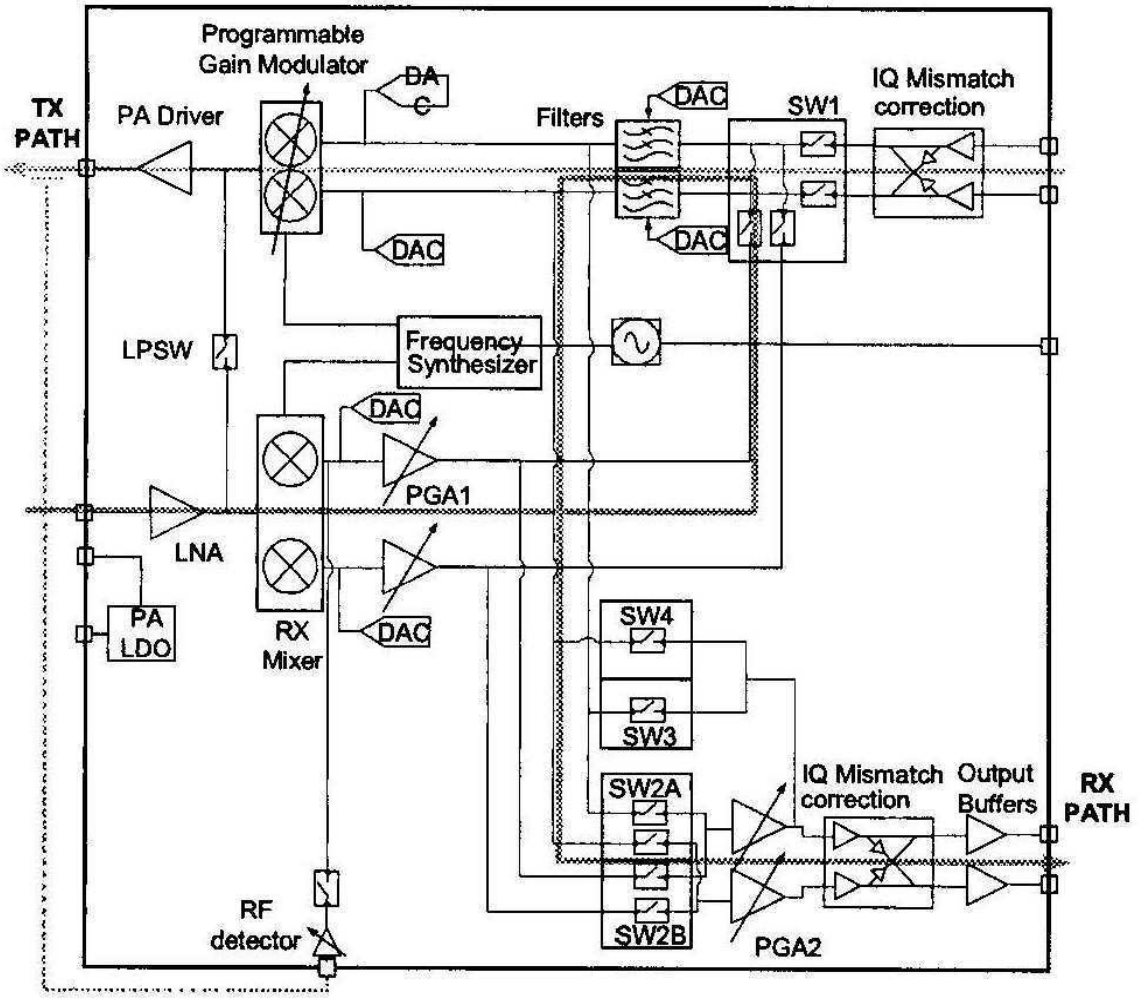
Dynamic Logic (1982)



Dynamic Logic (1982)

- Dynamic logic made the usually easy task of simulation digital logic very complicated
  - Device models had to have accurate leakage characteristics
  - The simulation of “floating nodes” sometimes lead to problematic results
- However, these were problems that could be addressed fairly easily, but which confounded timing simulators

RF CMOS Circuits (1988)



RF CMOS Circuits (1988)

- When device f_T values reached the point where wireless circuits became possible, the analog EDA landscape was changed
  - A new class of steady-state simulators, like SPECTRE-RF, Eldo-RF, and HSPICE-RF, were introduced
  - Device modeling had to model derivatives correctly for distortion
  - Noise analysis and distortion analysis became critical

Conclusions

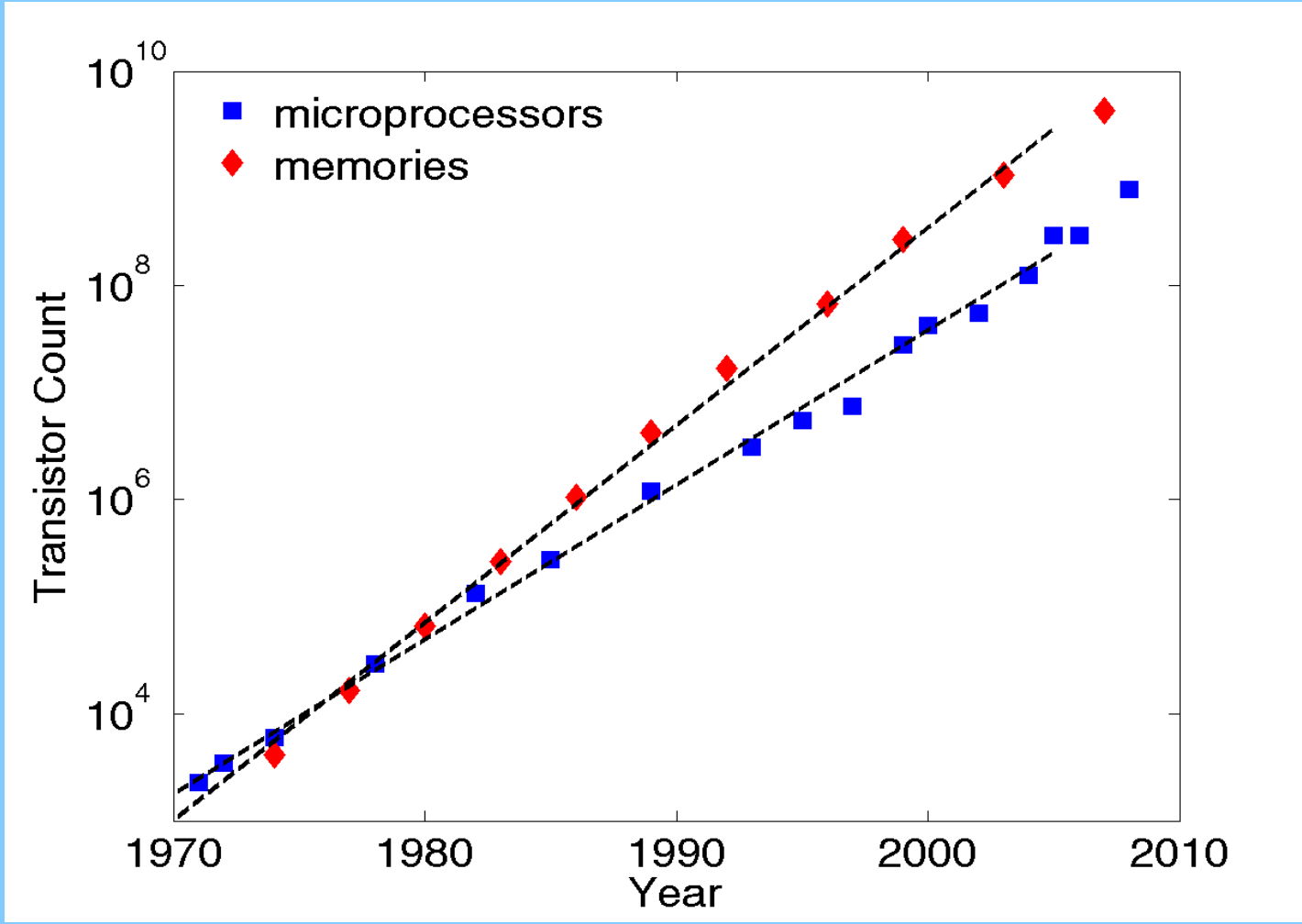
- Analog EDA tool development has always been reactive since tool requirements are hard to predict
- The need for new tool capabilities never replaces the need for legacy capabilities
- Designers will rely more and more on behavioral modeling and simulation
- The life of an EDA tool developer will be crazy well into the foreseeable future

Moore's Law

"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer."

Gordon Moore, *Electronics Magazine*, 1965

Moore's Law


microprocessors
memories
Transistor Count
10^{10}
10^{8}
10^{6}
10^{4}
1970
1980
1990
2000
2010
Year