Analog Electronic Circuits

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http://www.ee.bgu.ac.il/~analog

Electronics Training – ECE, BGU (circuits/VLSI track)

Electronics training "chain" (under the circuit/VLSI track)

- Undergraduate:
  - Intro. to Analog Circuits
  - Digital Circuits
  - **Analog Electronic Circuits – THIS COURSE (aka Analog IC)**
  - Intro. to VLSI
  - VLSI Design (aka mixed-signal IC design)
  - Switch-Mode Power Supplies (aka DCDC)
- Graduate:
  - Problems in Electronic circuits
  - Digital control of switch-mode systems

Logistics

- Lecturer: Prof. Mor M. Peretz
- Course hours: Sundays, 14-17
- Office hours:
  - PEMIC Center, Building 64, Rm. 4 (ground level)
  - Wednesdays 14-15
- Course website:
  - http://www.ee.bgu.ac.il/~analog
  - Slides will be updated before class
  - Videos will be uploaded during the semester
- Grading:
  - 100% final Exam

***Attendance is not mandatory but highly recommended

Analog Electronic Circuits
Course background and motivation

- Analog (continuous-time) signals
  - Continuous flow of information
  - Data derived from signals parameters: shape, amplitude, frequency
  - In Digital the info is discrete and finite

truscottjewellers.co.uk

sapling-inc.com

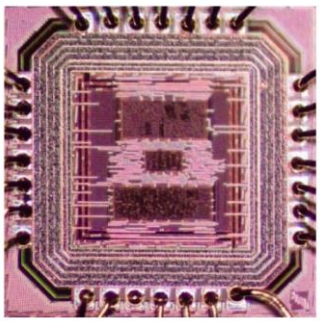
Analog Electronic Circuits
Course background and motivation

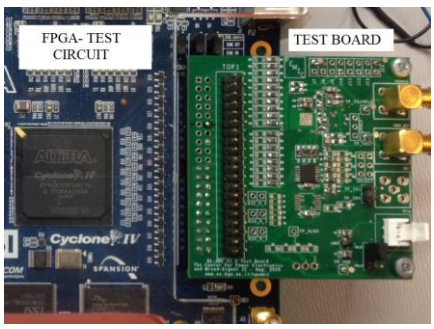
- We live in an ANALOG world (still…)
- The digital Revolution:
  - Simple designs, compact, scalable, upgradable, communication, fast time-to-market
- Any link to the "real world" needs interface
  - Computers, Mobile, Audio, Video, Communication

- $$$ The bottom line $$$
  - Electronics hardware engineers, in particular mixed-signal (analog) are *top earners with longest prospect across the board of hi-tech industry*

Integrated vs discrete circuits

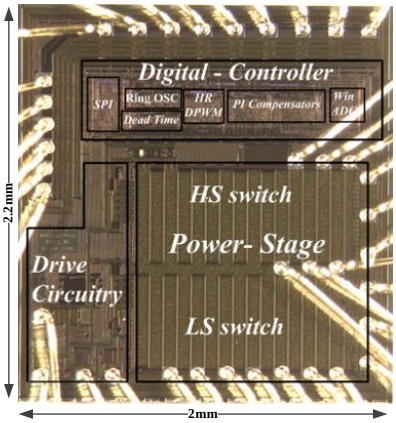
Die micrograph





Integrated vs discrete circuits

(a)



(b)

Recommended literature

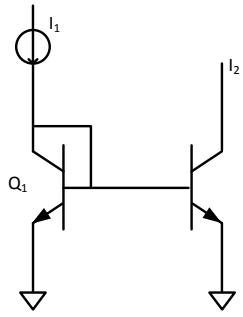
- Course slides
- Sergio Franco, “Design With Operational Amplifiers And Analog Integrated Circuits” (any addition)
- Ramakant A. Gayakwad, “Op-amps and linear integrated circuit technology:
- David A. Johns, Ken Martin, “Analog Integrated Circuit Design”
- Hans Camenzind, “Designing Analog Chips”

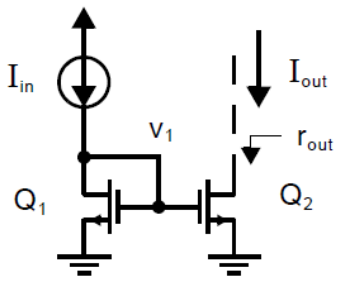
- Analog IC Design - http://www.aicdesign.org/
- Analog Electronic circuits - http://www.ee.bgu.ac.il/~angcirc

Lesson #1 Outline

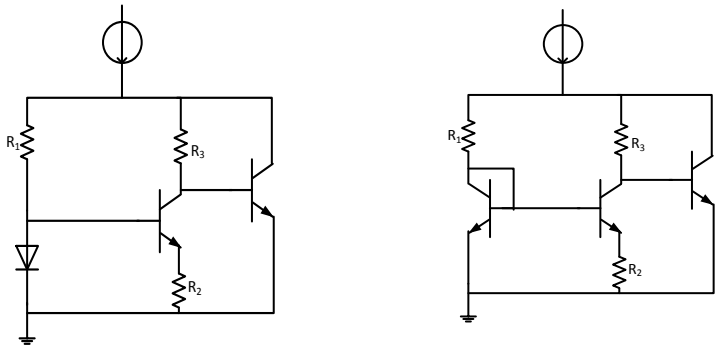
- Review of basic transistor circuits
  - Current mirrors
  - Voltage reference (Bandgap)
  - Differential pair
- The operational amplifier (opamp)
  - Basic internal (transistor) circuit
  - Ideal amplifier
  - Characteristics of the ideal opamp
- Basic circuits
  - Inverting amp, Non-inverting amp
  - Summing, difference, integrator, differentiator
- Additional applications
  - Voltage reference, current source

Current Mirror

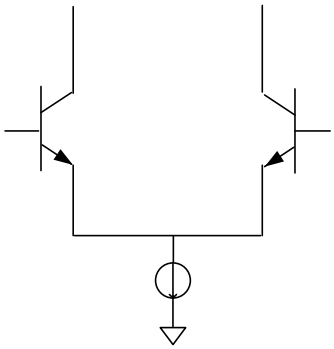


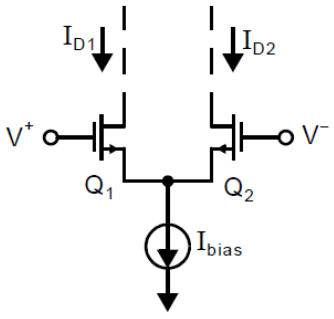


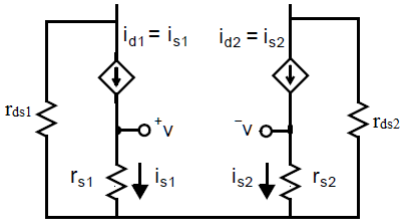
Voltage Reference (Bandgap)



Differential Pair







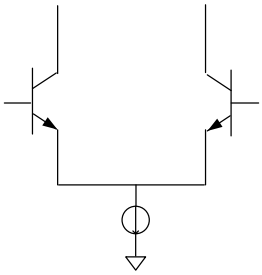
$$i_{d1} = i_{s1} = \frac{v_{in}}{r_{s1} + r_{s2}} \qquad r_s = 1/g_m$$

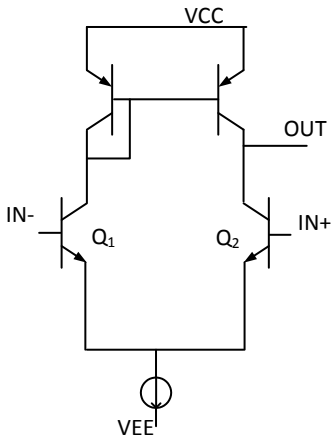
Q_1 and Q_2 have the same bias currents $\rightarrow g_{m1} = g_{m2}$

$$i_{d1} = \frac{g_{m1}}{2} v_{in} \qquad i_{d2} = i_{s2} = -i_{d1} \rightarrow i_{d2} = -\frac{g_{m1}}{2} v_{in}$$

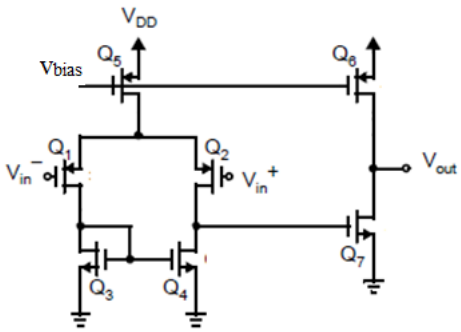
$$i_{out} \equiv i_{d1} - i_{d2} \rightarrow i_{out} = g_{m1} v_{in}$$

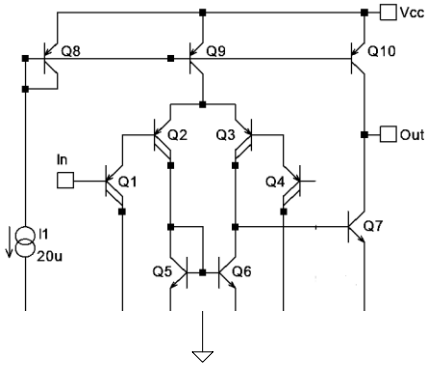
Differential Pair



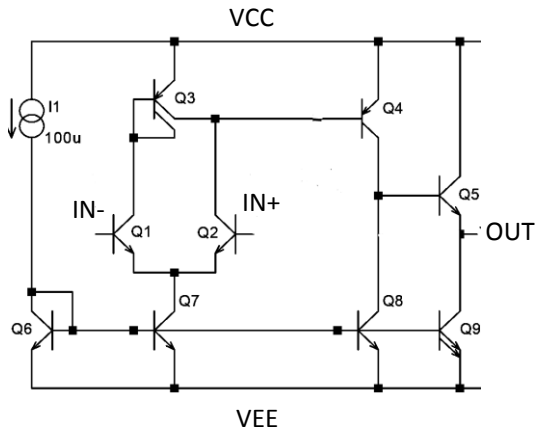


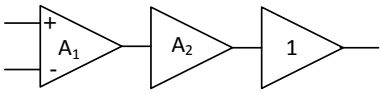
Differential Pair
Two stages



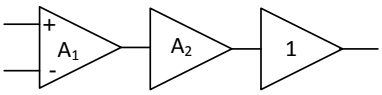


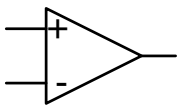
Three stages diff. pair – The Operational Amplifier

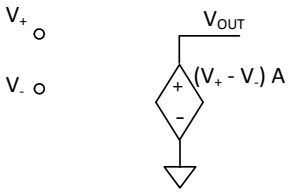




OpAmp characteristics



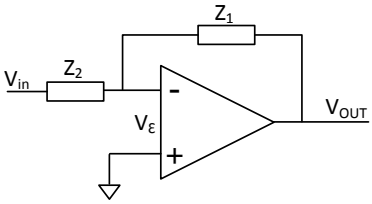




Ideal OpAmp primary features:

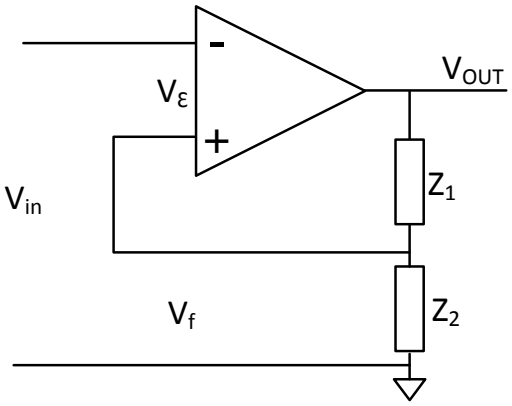
- Differential inputs
- Output product as function inputs ($V_+ - V_-$) A
  $A=A_1A_2A_3$
- Infinite gain $A \rightarrow \infty$
- Infinite Bandwidth $BW \rightarrow \infty$
- Infinite input resistance $R_{in} \rightarrow \infty$
- Zero output resistance $R_{out} \rightarrow 0$

Inverting Amp
Virtual Ground

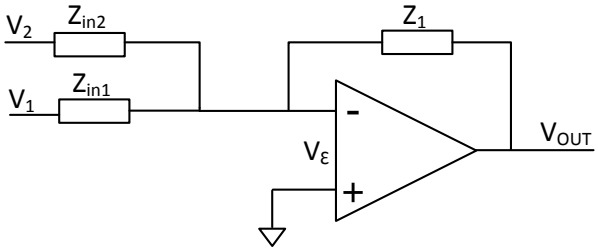


- Zero potential between inputs

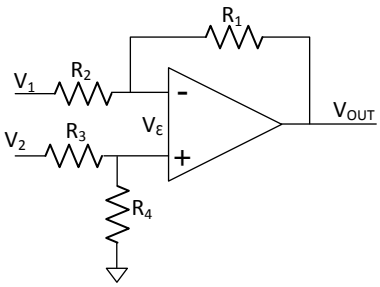
Non-inverting Amp



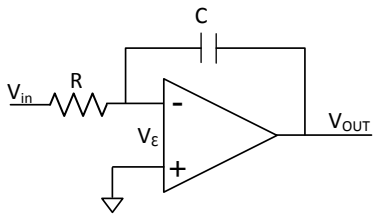
Summing Amp



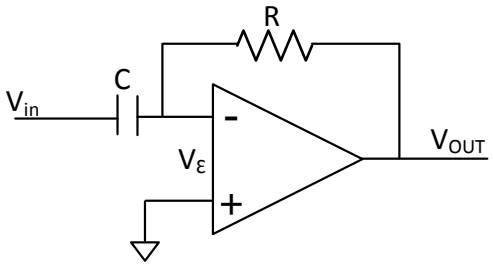
Difference Amp



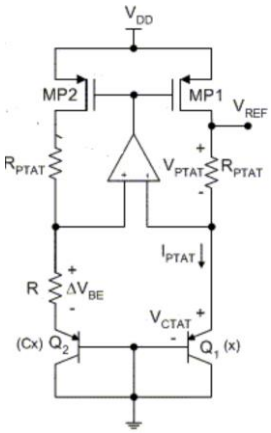
Integrator Amp



Differentiator Amp



Voltage reference by OpAmp (Bandgap)



Current source by OpAmp