TÉCNICO LISBOA

# Circuit Theory and Electronics Fundamentals

Lecture 26: Closing Lecture

# Basic circuit theory

- Basic circuit theory and electronics for Physics and Aerospace engineers
- Resistors, voltage and current independent and dependent sources
- Circuits and the Kirchhoff laws
- Parallel and series association of impedances
- Voltage Divider and Current Divider circuit configurations
- Superposition Theorem
- Systematic analysis methods:
  - the nodal method
  - the mesh method

# Circuit analysis modes

- **DC analysis**: circuit with time-invariant voltages and currents
- Capacitors, Inductors and Transformers
- Natural and forced circuit responses
- **Transient analysis** after on/off switching of constant voltage and current sources
- Forced, steady-state sinusoidal response
  - Because signals can be decomposed into sine waves
- Transfer functions and frequency response: **AC analysis**

# Semiconductor electronic components: diodes

- Semiconductors: electron and hole currents
- Intrinsic and Extrinsic semiconductors
- P-type and N-type extrinsic semiconductors
- PN junctions: diodes
- Diode operating point (non-linear DC analysis) and **incremental analysis** (linear AC analysis for OP deviations)
- Diode model: DC voltage source + incremental resistor
- Diode circuits: limiters, rectifiers, envelope detectors, voltage regulators

# Semiconductor electronic component: BJT

- NPN and PNP junctions: Bipolar Junction Transistors (BJT)
- The BJT as a controlled current source
- BJT operating point (non-linear DC analysis) and incremental analysis (linear AC analysis for OP deviations)
- BJT model: the Ebbers-Moll model (diodes and dependent current source) + Early correction ($V_A$)
- BJT circuits: common emitter (voltage) and common collector (current) amplifiers

# Semiconductor electronic component: MOSFET

- Metal-Oxide-Semiconductor Field Effect Transistors (MOSFET)
- The MOSFET as a controlled current source
- MOSFET operating point (non-linear DC analysis) and incremental analysis (linear AC analysis for OP deviations)
- MOSFET model: the quadratic dependent current source model + channel length modulation (λ)
- MOSFET circuits: common source (voltage) and common drain (current) amplifiers

# Semiconductor electronic component: OP-AMP

- OPerational AMPlifier (BJT or MOSFET)
- The OP-AMP as packaged transistor sub-circuit (BJT or MOS)
- The ideal OP-AMP is a linear component with
  - Infinite voltage gain
  - Unbounded output voltage
  - Infinite input impedance
  - Zero output impedance
- Non-ideal OP-AMP models include
  - Finite voltage gain
  - Supply voltage bounded output voltage
  - Finite input impedance
  - Non-zero output impedance
  - Input offset current and offset voltage
- OP-AMP circuits: inverting amplifier, non-inverting amplifier, addition and subtraction circuits, integrator and differentiator circuits, filters with OP-AMPs

# Transversal competencies: enjoyed by future employers

- Theory lectures and lab assignment materials taught in English (positioning Técnico as an international school)
- Extensive use of computers for calculations, programming (Octave), circuit simulations (Ngspice), and automatic text processing (Latex)
- Use of an engineer-friendly operating system: Linux (Ubuntu)
- Use of collaborative networked workflows: git as a powerful project management tool
- Lab assignments that provide design freedom, teach engineering trade-offs, stimulate both cooperation and healthy competition among teams, while promoting the understanding of the course materials rather than the brainless execution of steps
- Use of an open discussion forum and instant messaging tools
- Stimulate the use of open-source tools as they are free and reliable, many times more than commercial tools, benefiting entrepreneurs

# Final remarks

- Keeping the base course program, the course materials have all been developed from scratch, in real time… and with eventual typos and mistakes:
  - Philosophy: don’t wait until everything is perfect; when you finish, it may no longer be needed
  - Philosophy: design, fix what you can, and get it into the hands of the users; they will enjoy early access and help you fix it. The ***Ship-Then-Fix*** approach!
- All lectures have been recorded and made available as well as the lecture slides
- Course was under staffed by design or lack of resources – the lecturer was working twice the normal class time… (delegates, talk to coordinators to solve this problem in the future)
- Final message for Physics and Aerospace engineers: you may need to use or make electronic equipment in your future profession – consider doing your dissertation on an electronics related field