# MAE 221 Laboratory Summary

Through the sophomore initiative, the MAE 221 course has been revised for the fall of 2002. Previously, it consisted of 6 thermodynamics laboratory sessions followed by an independent project. In its present form the traditional independent project has been removed and replaced with 5 laboratory sessions devoted to analog electronics and tools for data acquisition and signal processing. The fifth session consists of a small independent project where the students their knowledge of the basic components and circuits to produce a more substantial device. These five electronics sessions precede the thermodynamics component. There will also be one lecture per week through which various instructors will provide background information.

The structure of this lab has been motivated by the following three philosophies:

1. Lab activities are based upon application. The goal is to motivate students by emphasizing practical engineering applications of the devices and clearly communicating the objectives to the students. Through this approach we hope to encourage active pursuit of the activities by the students, and avoid the 'cookbook' approach.
2. In the interest of providing context, the introduction of a new device is frequently motivated by the failure of a previously studied device under certain conditions. This leads to a rather unique presentation of the material. For example, op-amps are introduced through the application of a voltage follower to increase the input impedance of a load on a voltage divider. Transistors are not introduced until after the op-amp. Students will first observe that the op-amp can not provide enough current to drive a DC motor of moderate size so a transistor circuit will be used to amplify the current.
3. Following each lab, students will be required to generate a technical reference sheet for a specified device that is central to that lab. The objective is to provide the students with a series of concise references that they can use in future lab activities and work outside of this curriculum.

The following is a summary of the content of each lab.

**Lab 1: Laboratory Tools and Basic Resistive Devices**

Objectives:

- Become familiar with lab equipment: power supply, volt meter, and oscilloscope
- Become acquainted with lab software: Labview and OrCAD
- Review basic series and parallel circuit concepts
- Use a resistor as a current limiter, current to voltage converter, and voltage to current converter
- Build a potentiometer and understand its principle of operation
- Understand voltage dividers
- Understand input impedance

1. Introduction to laboratory instruments
   - trainer, power supply, multi-meter, oscilloscope, LabView
   - identify connections and controls
2. Basic circuit concepts
   - become further acquainted with the equipment while reviewing series and parallel circuit concepts
   - transforming function of a resistor
3. Voltage division and regulation
   - the voltage divider
   - the voltage regulator
4. Application of a load to a voltage divider (input impedance)
5. The resistor as a current limiter
   - introduce load lines and curve tracers (resistor, diode, light bulb)
   - protection of a diode with a resistor
   - current limiting feature of a light bulb
6. Construction of a potentiometer
7. Potentiometer application: variable resistor (qualitative)
8. Potentiometer application: voltage divider (qualitative)
9. Performance specifications of the potentiometer
   - resistance, linearity, thermal properties
10. Potentiometer application: dynamic displacement measurement (quantitative)
11. Real potentiometers
    - investigate construction, review data sheets
12. Construct data sheet for potentiometer.

**Lab 2: Filters and Operational Amplifiers**

**Objectives:**

- Understand low-pass RC filters and design one to remove noise from a signal.
- Understand Operational Amplifiers and use them in the following devices.
- Construct a voltage follower to solve the input impedance problem in the last lab.
- Construct a linear amplifier to enhance small signals
- Construct a summing linear amplifier and use as a current to voltage converter
- Construct integrators and differentiators. Convert displacement to velocity and vice versa.

1. Removing noise from a signal and a power line
   - build a low-pass RC filter to remove noise from dynamic displacement signal in Lab 1
   - build RL choke to filter a power supply line
2. The voltage follower – a better solution to the input impedance problem
   - introduce op-amps
   - use as a buffer between voltage divider and load to get reliable division factor
3. The linear amplifier: amplifying small signals
   - also use to drive a motor. Demonstrate current limitation.

4. The summing linear amplifier: current to voltage conversion in a digital to analog converter
5. Integrators and differentiators: determining displacement from velocity and velocity from displacement

**Lab 3: Power Sources and Power Control**

**Objectives:**

- Understand transistor operation
- Construct and understand common transistor devices:
    - Use a transistor as a current regulator to charge a battery
    - Use a transistor as a switch
    - Build a push-pull amplifier to increase current to a motor
- Use a transformer to drive a synchronous AC motor
- Construct an unregulated DC power supply with a bridge rectifier, and study a real power supply

1. The transistor
   - testing with a multi-meter
2. Regulating current with a transistor: a battery charger
3. The transistor switch
4. Amplifying current: driving a low voltage DC motor
   - torque/speed measurement
5. Speed control on a 100V synchronous motor
   - transformer
6. Construction of an unregulated DC power supply
   - bridge rectifiers and filters
   - observe ripple using a high-pass RC filter
7. A real DC power supply

**Lab 4: A Variety of Sensors and their Calibration: Measurement of Temperature, Force, Pressure, Position, Velocity, and Acceleration**

**Objectives:**

- Become familiar with the implementation and performance of a variety of 'small signal' sensors, including:
    - Optical position detection and communication
    - Piezo-electric pressure transducers and accelerometers
    - Thermocouples
    - Hall effect proximity detectors
    - Acoustic proximity detectors

- Become familiar with the implementation and performance of a variety of 'bridge-type' sensors, including:
    - Strain gauges
    - Thermistors

- Linear Variable Differential Transformers (LVDT's)

1. Small signal sensors (use linear amplifier + filter + current amplifier)
    - optical
        - position sensing
        - fiber optic communication
    - piezo-electric
        - diaphragm: pressure
        - accelerometer: acceleration and vibration
    - thermocouple
    - magnetic: Hall effect tooth detector for gear
    - acoustic

2. Bridge-type sensors (use bridge + differential amplifier)
    - strain gauges: force
    - thermistor: temperature
    - LVDT: position

**Lab 5: Independent Projects**

**Objectives:**

- Implement previously studied components in a simple but practical electronic device.

1. Position Servo
2. Temperature Regulator
3. Recording Loop
4. deProny Brake
5. Hotwire Anemometer
6. MUX/DEMUX multi-channel
    - pulse-width to voltage level using integrators