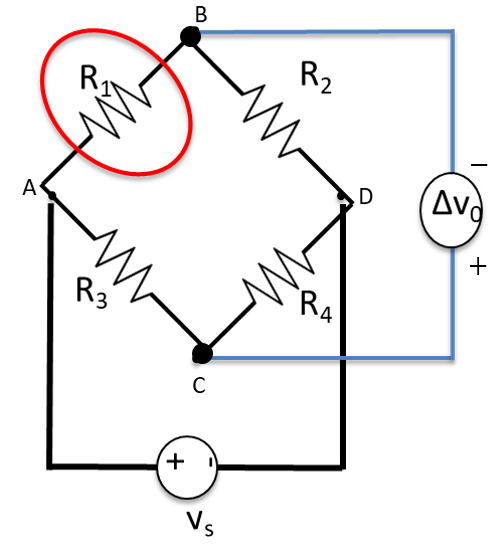
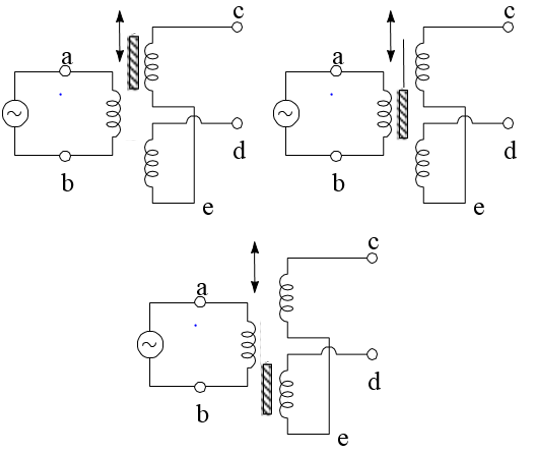
1. What is the initial output voltage (before any voltage has leaked off) of a 1-cm2 piezoelectric sensor composed of a 150-µm thick PVDF film when it is exposed to the applied force caused by a 20 g weight, with 23 pC/N, and ϵr,PVDF = 12? [hint(s): *f = ma, 1 N = 1 kg m/s2*, ϵo = 8.85E-12 F/m]
2. A thermistor temperature sensor placed in a bridge circuit has been put in a biomedical application to measure the temperature of a neonate’s body temperature, which provides feedback to a thermal blanket used to keep the neonates body temperature close to 37 oC. The following bridge circuit shows the thermistor represented as R1. If R3 and R4 are fixed at 1kΩ, and the calibrated resistance at T0 = 0 oC, R2 = 500Ω, with a supply voltage of 10V, and α = 0.00395/oC, what is the measured bridge voltage *Vo* for a temperature of 37 oC? What is the difference in voltage measured if the neonates body temperature drops from 37 oC to 34 oC?



Answer:

**Problem 3:** For the LVDT shown in Figure A, sketch the voltages c-e, e-d and c-d as a function of time when the core is (1) in the top position, (2) in the middle position, and (3) in the bottom position shown. (You will generate three graphs of voltage vs. time, one for each position, each graph having three curves.) Assume that the frequency of the oscillator in the figure is 1 kHz. (See Lecture 6, Slides 10 and 11).



**Figure A:** Inductive displacement sensor based on a differential transformer.

**Problem 4:** You have a sensor that measures velocity. You can convert it to displacement sensor if you integrate the output over time.

1. Assuming that the output impedance of the sensor is low but unpredictable (on the order of 50 , but possibly as low as 20 and as high as 100 ), and that the calibration factor for the sensor is 1 Volt/(mm/s), sketch an operational amplifier circuit that provides a voltage calibration factor of 10 Volt/mm.
2. If the velocity sensor had an offset (finite output for zero velocity input), why would that be problematic to the circuit you designed in Part a.
3. If you now want a transducer that responds to acceleration, how could you add an operational amplifier circuit to the original sensor to obtain an accelerometer with a calibration factor of 0.05 V/(cm2/s)?
4. If the sensor’s output impedance is large and unpredictable (possibly as low as 100 k and as high as 1 M) and you want the calibration factor to be positive, how could you modify the circuit in Part a.

**Problem 5 (Electrical Safety):** A subject with wet hands grabs a 10 Volt RMS power line with one hand and grounds himself with the other over two seconds. Deduce

(5 pts) The amount of current that passes through the subject.

Human skin has about 1k resistance, so the current is v/R=10mA.

(5 p[ts) The most likely consequences of the current to the subject.

This current is low end of the let-go current. Most likely, the subject will be able to feel the current, with a warning sensation.

**Problem 6: (Lecture on Sensors and Bridges, “Inductance (Capacitance) Bridge” slide)** A variable inductor is used as its main sensing element for a given biomedical measurement. The inductance of this element changes in proportion to the signal of interest. The inductor is placed in a Wheatstone bridge configuration, with three unchanging inductors as the other three arms of the bridge. Sketch the circuitry required to translate the inductance to a DC signal.

**Problem 7:** Sketch a setup that you could use to measure the rotation rate of a DC motor, where your primary sensor is each of the following (i.e. sketch a total of 5 setups). Assume that the motor drives a disk and that it is the rotation rate of the disk that you will directly measure. (I am interested in how the rotation rate of the disk alters some characteristic of the sensor, how that change in the characteristic is translated to a voltage, and how a voltage is translated to the rotation rate. E.g., for 4, how would the rotation of the disk change the dial position, how can you convert the dial position to a voltage, and how can you use the voltage to deduce rotation rate? You do not need to provide details of the voltage to frequency conversion circuit, if such a circuit is needed. Also, refrain from placing any of the electronics on the disk itself so that wires do not become twisted as the disk rotates.)

1. A photoresistor (perhaps in combination with a laser)
2. A strain gauge
3. An inductor (perhaps in a bridge circuit)
4. A dial potentiometer
5. A thermocouple

**Problem 8:** (Thought exercise) Tachometers generally count the number of events in a given amount of time (such as the number of times light is reflected from a reflective surface that rotates with the rotating target). This strategy will not distinguish between clockwise and counter-clockwise rotation. How could you modify this strategy or devise a new strategy to provide a signal that is positive for a clockwise rotation and negative for a counterclockwise rotation?

Answer:

A switch can be added that turns on during clockwise rotation and off during counter-clockwise rotation. The switch can be used to direct the Tachometer output directly as a positive output for clockwise rotation, or through an inverting amplifier to get negative output for counter-clockwise rotation.

A gyroscope can be used to detect clockwise or counterclockwise rotation.

**Graduate Content**

**Problem 9:** Use LTSpice to model the two full-wave rectifier circuits (one LTSpice model per circuit) shown in Lecture 5. The first is based on simple diodes. The second is based on MOSFET transistors. Since you will need to feed the and signals to a differential amplifier, use the LT1168 chip. Run the simulations with a 1 kHz, 5 volt amplitude sine wave. Comment on the quality of the two rectifiers. Which provides a more accurate rectified signal?

**Answer**

**Diode Rectifier**

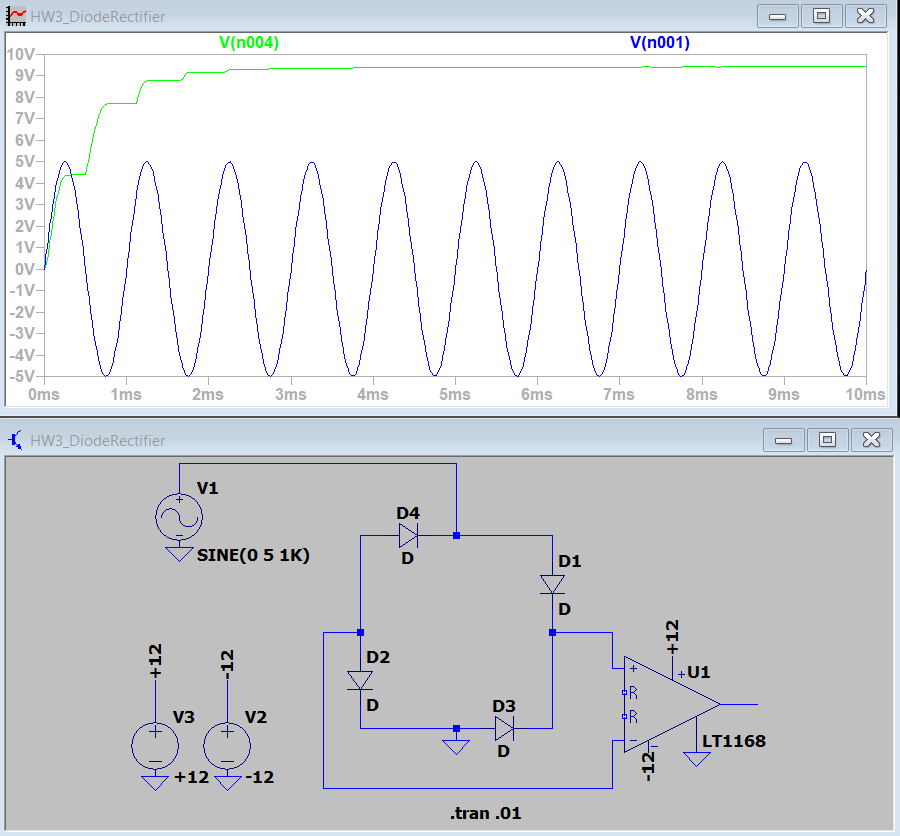
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Figure : Diode rectifier.

**MOSFET Rectifier**

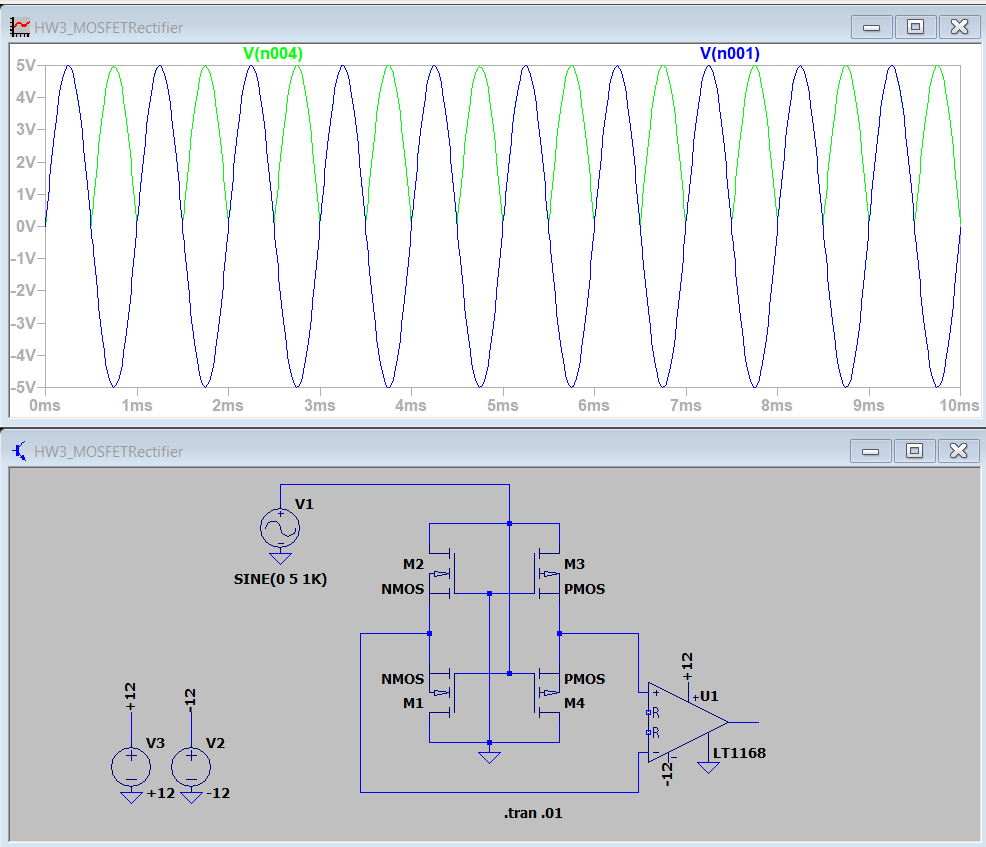
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Figure : MOSFET rectifier