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Hands-on lab exercise: Energy and Power consumption

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Introduction

This note describes the hands-on lab exercise concerned with the energy and power consumption of the HW Mote. The exercise assumes you have followed the first two exercises and is familiar with TinyOS , NesC, and the TelosB HW Mote.

Setup

Figure 1 shows a Mote equipped with necessary HW to measure the power and energy consumption using an oscilloscope.

Figure 1: Battery based Mote with shunt resistor.

We want to find the power - *Pmote(t)*- and energy - *Emote(t)* - consumption of the Mote, i.e.:

$$Pmote(t) = Umote(t) \cdot Imote(t) \qquad [W = V \cdot A]$$

$$Emote = \int_{t0}^{t1} Pmote(t)dt \qquad [J = W \cdot s] ,$$

where *Imote(t)* is the current drawn by the Mote and *Umote(t)* is the voltage across the Mote, at any time *t* ([s]), *t0* and *t1* is the time frame we want to calculate the energy.

To be able calculate the energy we thus need to measure/calculate *Imote(t)* and *Umote(t).*

First, let’s look at a few simple laws and equations that we will use in the exercise.

To be able to measure the current consumption *Imote(t)*of the TelosB Mote at time *t,* a shunt resistor *Rshunt* is inserted (in series) between the batteries and the Mote. Then connecting the oscilloscopes to the two terminals of the shunt resistor (using the probe) makes it possible to measure the voltage across the shunt resistor *Ushunt(t).* Ohms law gives us the relation between the current consumption and the (small) voltage across the shunt resistor:

$$Ushunt(t) = Rshunt \cdot Ishunt(t) \qquad [\text{V} = \Omega\cdot\text{A}],$$

i.e.

$$Imote(t) = Ishunt(t) = Ushunt(t)/Rshunt \qquad [\text{A}]$$

where *Rshunt* is the value of the shunt resistor.

The voltage across the Mote *Umote(t)* is given by:

$$Umote(t) = Ubattery(t) - Ushunt(t) \quad [\text{V}],$$

where *Ubattery(t)* is the battery voltage of the 2xAA batteries in series.

The power consumption by the Mote at any time *t* is then:

$$Pmote(t) = Umote(t) \cdot Imote(t) = (Ubattery(t) - Ushunt(t)) \cdot Ushunt(t)/Rshunt$$

The energy consumed by the Mote during the time frame from *t0* to *t1* is then:

$$Emote = \int_{t0}^{t1} P(t) \cdot dt = \int_{t0}^{t1} (Ubattery(t) - Ushunt(t)) \cdot Ushunt(t)/Rshunt \cdot dt$$

If we assume these values (*Ubattery, Ushunt, Rshunt*) are constant (is this realistic?) in the time frame *t0* to *t1* we get:

$$Pmote = (Ubattery - Ushunt) \cdot Ushunt/Rshunt$$

$$Emote = (Ubattery - Ushunt) \cdot Ushunt/Rshunt \cdot (t1 - t0)$$

I.e. we can estimate the power and energy consumption by measuring the *Ushunt* on the oscilloscope in the time-frame from *t0* and *t1* assuming *Ushunt* is constant. (What do we need to do if *Ushunt* is not constant?).

LEDs

In the first exercise we will measure the power and energy consumption of using the LEDs on the Mote.

First make a program that just power the Mote up (no activity)

- Measure with the oscilloscope the voltage across the shunt resistor using a 1 ohm resistor and determine the power consumption of the Mote in this mode. How accurate is this number?
- Optional: Substitute the 1 ohm resistor with a 10 ohm resistor and determine the power consumption of the Mote in this mode. Any difference?

Then make a program that switch 1, 2, and 3 LEDs on (steady-state)

- Using the oscilloscope together with the 10 ohm resistor to measure the voltage of the Mote when 1, 2 or 3 LEDs are switched on. Determine in each case the power consumption of the LEDs.

Then make a program that periodic (e.g. 250ms) switch the following scenario …. 0 -> 1 -> 2 -> 3 -> 2 -> 1 -> 0 …. (# of LEDs)

- Using the oscilloscope together with the 10 ohm resistor to measure the voltage over time of the Mote. Why are the voltage steps different in magnitude?

Temperature measurements and radio communication (if time left)

In this exercise we use one battery based Mote (source) to make temperature measurements, and one laptop based Mote (sink – base station).

First, make a program where the source Mote makes one temperature measurement each second and transmit this to the sink Mote. Keep radio on all the time.

For simplicity you can start to use broadcast (default) on the source Mote.

- Use the oscilloscope together with the 10 ohm resistor to measure the current consumption of the source Mote when transmitting the temperature measurement. Determine the average power consumption of the Mote in this mode.
- Is the source Mote during this scenario in receiving (listening) mode at any time?

Then modify the program to only power up the radio (on the source Mote) when it needs to transmit the temperature measurement. Otherwise, the radio should be in sleep (power down) mode.

- Determine the average power consumption (on the source Mote) when the radio is in sleep mode.
- Determine the average power consumption (on the source Mote) when the radio is in active mode.
- How much energy (on the source Mote) does is cost to take and transmit 60 measurements (1 min)?
- Is the source Mote during this scenario in receiving (listening) mode at any time?

If you have time left, then modify the program to collect temperatures over 1 min; and only power up the radio (on the source Mote) after 1 min (60 measurements) and transmit all 60 measurements in a burst. Following return the radio to sleep. Make a program that does this continuously.

- Determine the average power consumption (on the source Mote) when the radio is in sleep mode.
- Determine the average power consumption (on the source Mote) when the radio is in active mode.
- How much energy (on the source Mote) does is cost to take and transmit 60 measurements (1 min)?
- How much energy is saved compared to the previous setup?