Song-Hee Paik
6.191
Thesis Pre-Proposal
12/07/01

Design of Low-Noise Amplifier End for Non-Intrusive Monitoring of Air Flow in Buildings.

Advisor: Professor Steven Leeb

With rising costs of energy, knowledge of electricity consumption and time of use in homes and buildings is vital to consumers and electric utilities. Not only is this information tied to billing and payments, it could potentially indicate the need for conservation activity or load control. This increased interest in energy score-keeping, load forecasting, and improved control of electricity-consuming equipment has focused attention on the instrumentation required to obtain the desired data. With an arbitrarily complicated sensor network, the task of acquiring such data would be straightforward. However, given the costs of energy, as well as the desire to avoid having a mess of wires everywhere, there is a need to monitor power consumption without using elaborate, power-consuming methods. In short, methods to gather data should be “non-intrusive.” One of the areas of research in Professor Leeb’s group is finding ways to acquire this data without excessive instrumentation.

One approach formulated under Professor Leeb is the non-intrusive load monitoring (NILM) algorithm. The basic idea of this algorithm is that individual loads can be detected and separated from rapid sampling of power at a single point serving a number of pieces of equipment, like a power meter of a house. From this single location, equipment start-up and shut-down can be centrally observed and analyzed based on changes in steady state power. Presumably, a step up in steady state power would correspond to something turning on, and a step down in steady state power would correspond to something turning off. Furthermore, different loads can be distinguished by matching start-up transients to known patterns. Irregularities in known patterns can contain valuable clues about faulty equipment operation, including unnecessary operation, failure to operate when needed, or gross changes in power when operating.

My project with Professor Leeb involves the regulation of air-conditioning in buildings through air flow detection. Air flow in buildings causes some rooms to be much cooler than others. Therefore, in the presence of air current, it is not necessary to uniformly cool all rooms. Unfortunately, temperature sensors have relatively slow response times, and rooms with an influx of air current tend to become uncomfortably cold before the temperature feedback system kicks in and turns the air-conditioning off. Thus, if air flow can be detected, buildings can save energy, as well as provide more comfortable temperatures everywhere! However, it is convenient and necessary that the air flow detection is done without excessive networks of wire, i.e. it is done non-intrusively.

The strategy being researched is to build transmitters that can generate ions and receivers that can detect them. Ideally, transmitters will be devices that can simply be plugged into an electrical outlet and will roughly function by creating strong electric fields from the voltage source to ionize the surrounding air. Air flow will move these ions around. On the other end, receiver circuitry need to be designed to detect ion arrival and output a signal proportional to the rate of ion arrival. The knowledge of the rate of ion arrival in various locations would then contain information about the movement of air in that building.

A tentative receiver topology is an operational amplifier with a capacitor in an integrator configuration. The ion arrival rate can be modeled as a very small current source flowing into the negative terminal of the op amp. An ion collides with the receiver with some velocity, and induces a charge on the capacitor, and the voltage at the output of the op amp increases. In this way, differentiating the output voltage gives the rate of ion arrival. The output of the op amp will likely be connected to a microprocessor. Outputs generated by NILM, which contain information about which air-conditioners are on and how high they are turned up, will also probably be inputs to the microprocessor. Based on this set of information, the microprocessor can then make decisions to adjust air-conditioning control accordingly.

My thesis project will be the design, implementation, and testing of the amplifier circuit for the receiver, and could possibly involve some interface with programming a portion of the microprocessor. Though exact specifications for the amplifier are not yet clear, the challenge of this project will be the ion detection mechanism, and the design of a low-noise, reasonably fast amplifier.

I have spoken with Professor Leeb about academic preparation for joining his group. I informed him that I have already taken 6.301, am currently taking 6.302, and plan to take 6.331 next term, and from his response, it seems that that will be sufficient background coursework. My rough schedule and work plan is something along these lines:

- Spring 2002: take advanced circuit design course (6.331).

- Summer 2002: begin research, read up on NILM.
- Fall 2002 / IAP 2003: design, build, and test lower-noise amplifier circuit and possibly program microprocessor.
- Spring 2003: finish classes needed to graduate, begin writing thesis.
- End of Spring 2003 / Summer 2003: graduate! (I hope!)

Also while talking with Professor Leeb, I have considered some possible obstacles while working on this project and potential alternatives. For one, current research in his group might conclude that ion transmitter/receiver approach is not a good idea. My alternative would be to research with his group to find a better approach for air flow detection; I am sufficiently interested in this problem itself to be willing to shift gears in my thesis project. Also, though Professor Leeb said research funding for the summer will not be a problem, he may not have funding for an R.A. position for the fall term. My alternative would be to TA 6.302. However, as I am taking 6.302 right now, and as I have also talked to my 6.302 TAs, I am concerned that TAing this class will be rather time-consuming to the point that I may not be able to get as much research work done as I need. Additionally, research funding for the spring term is also not certain, and I will need to complete some classes during my M.Eng year to be able to graduate. Hmm…