



Design Issues Paper

Automated Trace Gas Trapping System (ATGTS)

Due 11/19/2008

Team 7:

Dan Cashen

Chris Gliniecki

Thomas Hancasky

Alex Esbrook

Adam Grisdale

Josh Kowalski

Alex Kerstein

Product Lifecycle Management

Battery life

The system's month-long running time was the dominant concern of this project's electrical engineers for several weeks. Initial estimates of the energy required to keep the device working in the field were upwards of 100 AH at 12 V for 1.2 kWh of energy. Some components simply do not run for as long a duration as originally calculated, but as calculations were elaborated upon it was found that the system would draw approximately 50 AH prior to adding any sort of safety factor. Batteries capable of supplying this amount of energy are bulky, heavy, expensive, and potentially unsafe. As such, it was of the utmost importance to reduce the system's power consumption in any way possible.

A solenoid valve needs to be held open to route air through, and the electromagnets that give these components their name can draw moderately high currents, becoming warm to the touch very quickly. This dissipated heat is wasted energy and not necessary to keep the valve open. To reduce this, a driver circuit was found that supplies a spike of voltage from a capacitor when the component is initially switched on, then runs the valve at a reduced voltage afterwards. This circuit reduces the demands of the solenoid valves significantly.

To further reduce the power absorbed by the valves, the microcontroller was programmed to drive them using a pulse-width modulated signal with a duty cycle of 46%. The pulses are delivered in such quick succession that the valve is not in danger of snapping closed while the signal is low, yet it only draws additional energy from the battery while the signal is high, decreasing demand further.

The pump used to drive the air through the valves and traps runs on a DC signal, but always at 6V. Using a 12V battery and a buck converter, it was found that the current draw from the battery can be cut nearly in half, making the pump more efficient than the original estimate indicates.

One of the factors that made the original prototype created by Dr. Smemo unfeasible was the fact the microcontroller was kept active during an entire trial. Even though the chip draws fairly low currents on its own, when integrated over an entire sample period, it ultimately consumes more energy than any other component. To alleviate this, a simple timer circuit not unlike those used to time the activation of Christmas lights was employed. The timer circuit cuts off each of the other components from the battery, routing power to the rest of the circuit during a daily schedule as programmed by the user. The microcontroller is part of this circuit, and drives the rest of the routine upon activation. Once finished, the controller goes into a wait state until the timer deactivates it. The timer itself dissipates a current measurable in μA , using a watch battery to time out the daily schedule, therefore a negligible amount of energy is drawn from the battery.

These solutions reduce our systems energy requirements to 20 AH, which is deliverable by standard rechargeable batteries and allows us to employ a second battery to maintain a safety factor of two. Overall with the incorporation of a driver circuit, pulse-width modulated signal, buck converter, and timer circuit the total systems energy requirements was reduced from 100AH to 20AH.

Chemically Inert Plumbing

Present in the ATGTS plumbing are several potential sources of corrosion. Air is being pumped through a series of traps containing strong base materials that can deteriorate various metals and plastics. Over time, this erosion could compromise the integrity of the experiment by creating air leaks in the system.

In order to enhance the lifetime performance of the ATGTS plumbing, special consideration is given to the selection of materials for piping. In essence, each piping member must be composed of a chemically inert material. For this reason, each trap is composed of Stainless Steel or Aluminum to eliminate base material corrosion. In addition, the tubing used to connect components will be PEEK because of its good chemical resistance in the ATGTS's operating environment.

Fatigue Resistant Door

On the ATGTS, both the door exposing the ambient environment to the flux chamber and the sub-chamber housing door were originally designed to be made of PVC. However, once a pocket sliding door mechanism was chosen for both openings, wear between the Viton rubber seal and PVC became a major concern. It was decided, after deployment of the ATGTS in the field for several months, the PVC door would develop abrasions and a proper seal in both barrier locations would be inhibited.

In order to eliminate this fatigue problem without having to redesign the door mechanism or alter the dimensions of the door itself, the material was changed to Aluminum. Using an Aluminum door in both instances provides three advantages. First, as stated previously, the door will now not wear when rubbed against Viton over time. Second, using a light metal such as Aluminum won't inhibit door movement as much as a steel alloy would. Lastly, manufacturing a prototype of the door out of Aluminum is a fairly quick and simple process when compared with harder materials.

Heat Dissipation

Heat dissipation in a circuit can become a major problem when using power switching circuitry. In some instances heat sinks are needed to dissipate the energy lost as heat in a transistor. Fortunately, after some basic calculations and testing, it was determined that heat sinks are not required for this application. However, transistors do dissipate heat and that heat has to drift out of the product enclosure. After some calculation it was found that PVC will dissipate heat faster than the transistors will generate it. These calculations have to take into account the vast variety of operation locations. Fortunately, for this product, heat dissipation will not be a problem because the calculations show a high tolerance in maintaining operation activities with respect to temperature variations.

Ease of Product Deployment

A final concern for the ATGTS is the shipping of the device to and from its testing location. When sent using a major shipping supplier, the ATGTS will undergo a great deal of shaking and vibrations. Proper packaging of the device and the protection of internal components is of paramount concern.

The outer casing of the ATGTS is comprised of a heavy duty PVC cylinder. This outer casing will provide impact resistance during shipping while also shielding internal components from outside contact. Components such as the pump, valves, and traps will be individually secured to their respective locations inside the outer casing. Also, the cone shaped screen which covers the rain catch atop the device could be punctured or mangled during transit. Therefore, when shipped, the device will have a PVC sleeve placed on its top section to eliminate crushing the debris catch.

Environmental Issues

As with any device operating in outdoor environments, the effect of our device on its surroundings is of prime concern. The ATGTS does not ill affect the environment if running correctly. Power to the ATGTS is supplied by a lithium ion battery, which is clean and safe when operating under standard conditions. Also, all materials in the design are chemically inert; this prevents contamination of the surroundings. However, some key concerns are still present in regards to environmental safety.

The first major environmental concern comes from the lithium ion battery. While safe in normal use, there are a multitude of scenarios where the battery could be pushed outside its normal operational range. Should the ATGTS experience an electrical short circuit, the battery inside the ATGTS could explode or begin to leak due to overdrawing the battery. Lithium ion batteries are particularly volatile to explosions. To prevent this, fuses are included in our system to protect the battery and other components.

Another concern with lithium ion batteries is that they are susceptible to puncture and other forms of physical trauma. Many lithium ion batteries include an organic solvent to improve power density. If the battery is punctured or physically stressed, whether by physical trauma or overheating, the solvent can ignite and vent from the battery casing. In our design, the battery enclosure is isolated from the outside environment by a PVC outer case. This prevents leakage in the event of a battery explosion.

Another environmental concern comes from one of our chemicals, Carbosorb. This chemical is a strong base, and is hazardous to the environment and other carbon life forms in addition to humans. Despite the fact the traps are isolated from the ambient environment in the ATGTS; they do need to be replaced every month. During replacement, the Carbosorb may be exposed to the surroundings. The fittings we have provided on the chemical traps containing strong base automatically stay closed when the trap is removed. This prevents the Carbosorb from leaking out and contaminating the environment.

Product Safety

Safety is a large concern when designing a device for others who may not have the same technical background. The ATGTS will be powered by a 14.8V 25.2Ah lithium ion battery that can have up to a 14 amp discharge rate. This high potential of energy can delivery lethal amounts of current, weld materials together, start fires, or even explode. To avoid this special care must be used when handling and charging the battery. Lithium ion batteries come in cells of 3.7V each and batteries with larger voltages are made by combining cells together. A smart charger along with a protection circuit module must be used to monitor the levels of each of the batteries to prevent any of the cells from overcharging, which can cause the cells to overheat and explode.

Due to this potential hazard, fuses or breaker circuits are to be added to the power lines to prevent dangerous current spikes from damaging components or injuring people.

Another hazard of the ATGTS is the chemicals used in the traps. The Carbosorb used to collect samples in the CO₂ and N₂O traps is a basic material, which is corrosive and flammable. It should be handled away from open flames with protective gloves and eyewear to prevent exposure. Also the desiccant trap will contain molecular sieve which is used to absorb water from the air sample. Molecular sieve can cause skin, eye, ingestion, and inhalation irritation if exposed to directly or indirectly by generated dust. Prolonged inhalation exposure can cause lung injure and even cancer. These chemicals

will be contained by stainless steel enclosures and users must be aware of the precautions needed if these materials were to escape.

In order to eliminate the hazard created by the presence of Carbosorb in the ATGTS, each trap will be fitted with a manual Swagelok valve. When operated this valve will seal or expose the Carbosorb to the ambient air. By sealing the valves on either end of a trap prior to removing the trap from the ATGTS, spillage on an operators skin may be greatly reduced.