Witricity-Powered RC Car

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* Project Narrative Description:

The goal of this project is to facilitate the use and recharging of electronic devices by using Wireless Power Transfer (WPT) Technology, sometimes called Witricity. Our plan is to test this concept on an RC Car. This can be scaled in a later design to power electric cars, as well as to use the concept to power other devices. Ideally, the wireless aspect of this project will mean less hassle for the end user, and will help to reduce sources of malfunction in some cases by reducing the number of wires/ports needed to keep a device powered or charged. To show the quick response and applicability of the device, we will use a fast-charging, high-capacity array of capacitors.

The transference of energy will consist of several stages. The first stage is the conversion from standard 120V, 60Hz AC to a sufficient voltage DC, probably around 25-30V, before passing through a 24V regulator. The next stage will be a conversion from DC to 10MHz RLC stage, where the inductor is a large planar inductor around the size of 8”x8” (~20cmx20cm). The magnetic field of this inductor will be picked up by an equal receiver (both transmitter and receiver will have a resonant frequency of 10MHz for maximum efficiency). Finally, this AC signal will be made 12V DC in the same way it was earlier for 24V. The AC->DC->AC->DC configuration may seem redundant or perhaps unnecessary, but with the current availability/cost of components for AC/DC or DC/AC conversion, it would be both cheaper and easier to convert the 60Hz input signal to DC before making it 10MHz for the transmission stage. AC/DC conversion would only cost a few dollars for high-quality components, and bringing it back to AC can cheaply be done with an oscillating crystal.

In order to reduce interference with the normal operation of the car itself, the form factor will be light-weight and slim to the car’s chassis. Ideally, it will also be waterproof and sturdy. By being light-weight, it will not put a strain on the car’s motion. Being slim (or possible completely integrated save for the relatively massive planar inductor) will ensure that the inductor doesn’t hit the ground or any surrounding objects. The waterproofing will allow the car to run over puddles or mud without damaging the components, at least within the normal tolerance of the car. We’re not seeking for the model to be completely submersible, just making sure that the car is not more sensitive to water than it already is. Finally, it needs to be sturdy to ensure that the components don’t become loosened or detached from the repeated use of the vehicle.

The capacitors we will be using will be chosen based on three ideal principles. For this purpose, we want capacitors with high capacity, low drain, and medium to low dissipation of charge. With high capacity, the user will have the option of storing larger amounts of energy if the car is charged for a longer period of time. Low drain (high parasitic resistance) will mean that it will take significantly longer for the battery to naturally drain its energy, allowing for longer periods of storage. Medium to low dissipation of charge will come from having a relatively high series resistance with a good power rating, which will ensure that our capacitors, which naturally have a high rate of discharge due to a low internal ESR, don’t overload the circuitry of the RC car.

Optionally, we will also look a few other features after accomplishing the previously mention criteria. First, it would be ideal for the car to disconnect from the charging circuit when the car is fully charged or in use, to avoid the charging stage from acting as a load on the capacitors, which could drain more current from them. Such an implementation will also ensure that the capacitors don’t degrade faster from being constantly connected to the charging circuit. Second, the charging platform should have some type of etching or concavity to ensure that the car stays directly over the charger when charging. This structure should also be easy for the car to drive out when the charging is done. Lastly, the device could beep or flash some kind of light when voltage drops below a certain point to let the user know that it needs to be recharged.

* List of Specifications/Stages:
  + Stage 1: 120V AC/DC conversion (30V out)
  + DC Voltage Regulator (24V)
  + Stage 2: 10MHz DC/AC conversion
  + Stage 3: Receiver/Transmitter RLC circuit (10MHz resonant)
  + Stage 4: 10MHz AC/DC conversion (14-16V out)
  + DC Voltage Regulator (12V)
  + Stage 5: Capacitors and car load
* Specific Information:

This section will give specific quantities and explain why they were chosen. In stage one, 120V AC, which is a standard outlet voltage, will be converted to roughly 26-30V AC through a transformer, before being converted to a DC signal of the same range. This value will pass through a 24V regulator before passing through a crystal oscillator of roughly 10MHz. 10MHz is a relatively stable range for the transference of magnetic flux between the two large inductors, is not a common consumer frequency, and is not so high that it might cause interference with other devices. 10MHz is not a rigid requirement, but ideally it should be in the MHz range.

The efficiency of this circuit will not be 100%, therefore there is an expected voltage drop to be experienced. However, once the exact efficiency is determined, it will only need to be calculated for one distance, since the car will be in a fixed location when charging. As a result, the circuit needs to be designed such that the voltage reaching the second voltage regulator (12V) will be enough to overcome its dropout voltage. For this stage, 14-16V should be sufficient, and anything much higher will mean a large amount of heat will be dissipated in the regulator.

12V is picked so we can ensure the capacitors store a large amount of charge, which allows for a longer operation time. Many RC car batteries are generally rated at a range between 12V and 7.2V, so picking and designing for the high end of this range will mean we can apply this system to any RC car, not just low-voltage ones. The capacitors themselves will also be rated to hold at least 12V, and will most likely be in the order of 1F – 10F to store a desirable quantity of energy, and should ideally successfully run the car for close to an hour before needing to recharge. Anything too high and there would be far too much current. Too much current would cause permanent damage to the car, so some caution must be exercised. Since capacitors store and release energy very quickly, a lower operating time is not an issue, since we would also achieve a greatly lower charge time. It also means that, despite having potentially low energy storage compared to a battery, energy would still dissipate quickly enough to keep the car powered well.

* Budget and Financing:

This project should not cost much overall. A large cost means would be reflected in the market price, should this system be made readily available to customers. Capacitors themselves do not cost much and have several strategic sales points over traditional RC car batteries that make it acceptable for a capacitor array to have a slightly higher price. The expected cost of the capacitors should be under $25, and super capacitors provide a relatively cheap way of accomplishing this with the proper voltage. The wireless/charging component of this is fairly inexpensive, and is expected to cost no more than $50 total, which is a very generous estimate and may cost as little as $10-20. The car itself will probably be the most expensive component. Financing for the production of basic electrical components is being provided by Dr. Gong. The car itself we will most likely have to purchase on our own, and he is also providing the equipment with which to manufacture our planar inductors through lithography. Our budget for this entire project is under $100, but this should be more than enough.

* Milestones:

While nothing is set in stone, we have a general idea of where we want to be in both semesters of this project. Here is our current skeleton for planning/design and when we want to hit certain specific milestones:

* + - Week 1-2: Basic Concept
    - Weeks 2-4: Researching Project
      * Week 2: Proposal of Project
      * Week 3-4: Planning specifications
    - Weeks 4-6: Designing Experimental Procedures
    - Weeks 7-10: Conducting Experiments
    - Week 11: Final Report/Experimentation
    - Week 12: Preparation For Final Presentation

It should be noted that this is a rough schedule and will allow us to remain well ahead of our class timeline. So, if something undesirable should come up in one part of the experimentation or production, we will not be so limited by time that we are put in any danger of failing to meet the overall deadline of the class.