Voltage Regulator Circuit Project Report

Steven Sigley, Jr.

Writer's Comment: *This piece was a project report in memo format for an audience of varying degrees of knowledge. I focused this project report on a circuit I had designed and tested in a high school robotics class. By dividing the memo into sections, I allow the members of the audience to quickly find what information they need. Expert audience members can read through every detail of the report, while executive and technical audience members can skim right to the conclusion and ignore the complicated, unnecessary details. There is also an explicit section on finances for those who have to review the cost of the project's implementation. Writing this report was a great experience in technical writing using what project management experience I've already obtained. I'd like to express my gratitude for the support and comments provided by my writing teacher, Mr. Squitieri. Without his help, this report would not be the same.*

Instructor's Comment: *Steven Sigley wrote this strong Vanden Robotics memo for my section of UWP 102E Writing in the Professions: Engineering. In this course, students confront the challenge of learning to write effectively for multiple audiences in the workplace. This task requires that student writers make two basic conceptual adjustments. First, they must move beyond the model of conventional academic essay writing that they have learned to accept as normative throughout their high school and college careers; for most engineering students, this genre becomes obsolescent even before they leave the university. Secondly, these students must also transcend the conventions of the undergraduate lab write-up that they have practiced in their lower division courses, for although such write-ups usefully serve the needs of teaching assistants charged with evaluating immense quantities of undergraduate work, they fail to address the legitimate expectations of divergent professional audiences in the workplace.*

In his Vanden Robotics memo, Steven demonstrates that he has successfully made both these adjustments. Appropriately deploying an array of format cues (compartmentalization, white space, hierarchical headings, etc.), Steven has

designed his document in such a way that the different members (executive, expert, technician and lay) of his audience can each easily recognize and locate the sections he or she needs to review and just as easily ignore the others. In this way, the memo writer's document-design skill allows his colleagues to use their own time and talents more efficiently in the pursuit of a common organizational goal.

—Victor Squitieri, University Writing Program

VANDEN ROBOTICS

Memorandum

November 2, 2012

To: Eric Cesar, Engineering Director

From: Steven Sigley, Senior Engineer, Electrical Team

Subject: Recommendation to Finance Development of Printed Circuit Boards for Voltage Regulators to Replace the Current Dual Battery System

Distribution: Doug Green, Chief Project Administrator
Josie Murphy, Business Director
Katherine DeOsuna, Robot Technician, Electrical Team

As agreed upon in the meeting on October 15, the Electrical Team has designed a voltage regulator circuit to replace the current dual battery system with a single battery system, saving Vanden Robotics the expense of battery replacement. This voltage regulator circuit was based on three similar designs that were tested for durability and consistency. From the results of these tests, one was selected for further development. The expenses for PCB design and purchase were researched as well. This report provides background on the project, explains the circuit design, details the testing and results, analyzes the results, investigates development expenses, and recommends that Vanden Robotics fund the design and purchase of printed circuit boards for the final voltage regulator circuit.

Background of the Project

Vanden Robotics' executive committee met on the 15th of October, 2012, with the intention of finding ways to reduce robot expenses. The electrical team suggested that the dual battery system presently used to power the computer and motors could be changed into a single battery system and voltage regulator circuit. This circuit steps the voltage of the main battery down from 12 volts to 7.2 volts, allowing the computer to run off of the same battery as the motors, instead of using a separate battery. Removing the second battery spares Vanden Robotics replacement and charging expenses. This project, known as Battery System Replacement or Project #12-06, was approved.

Designing a Voltage Regulator with the LM317T

To design the circuit, the Electrical Team looked at the requirements for the voltage regulator circuit and determined that the project required an integrated circuit able to take in 12 to 13 volts from the main battery and output 7.2 volts at 50 milliamps to the robot computer. A candidate found to have all these qualities was the LM317 linear regulator from Texas Instruments (Part #LM317DCY). A technical document for the LM317 details how to implement a voltage regulator circuit using the LM317. Figure 1 shows how the voltage regulator circuit would be designed.

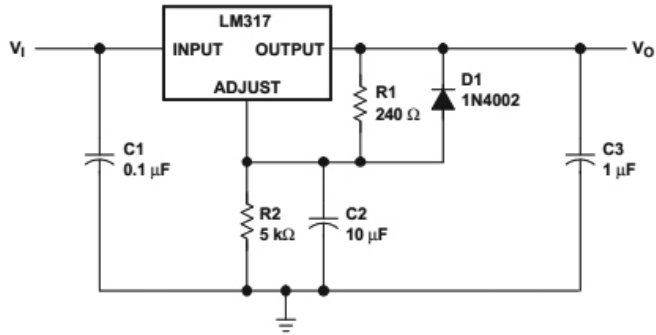

Figure 1.Texas Instruments 0 - 30 Volt Regulator Schematic.
Source: http://www.ti.com/lit/ds/symlink/lm317.pdf

This schematic proved useful in the layout of the circuit, but did not explain how the output voltage was related to the input voltage. However,

an equation in this same document detailed the ratio of resistor values needed to obtain a certain output voltage:

$$(1) \quad V_O = V_{ref}\left(1 + \frac{R_2}{R_1}\right)$$

The reference voltage for this particular component was given in the document as 1.25 volts. Accordingly, the ratio of R2 to R1 should be 4.76:1 or roughly 5:1 (given the circuit's inherent resistance) to obtain an output of 7.2 volts. Using this information along with the knowledge that the circuit used 12 volts and around 50 milliamps, the Electrical Team implemented two resistors in each circuit: a 5000-ohm, 1-watt resistor, and a 1000-ohm, 1-watt resistor. The wattage of the resistors was more than sufficient because even if all 50 milliamps ran through a single resistor at 12 volts, only 0.6 watts of power would be produced, not enough to damage the resistor.

With the resistors decided upon, the Electrical Team's attention turned to the final phase of circuit design for this project, heat dissipation. If the voltage regulator circuit overheated, it could fail. The LM317 had a simple built-in thermal protection circuit, but we were unsure if it would hold up to our needs. To avoid any failures due to heat, the Electrical Team made three circuits: one with no additional protections, one with a passive heat-dissipating heat sink, and one with the heat sink and a fan blowing heat away from the heat sink. These circuits were tested against each other to find the circuit with the simplest design that was effective for Vanden Robotics' needs.

Testing the Circuits' Ability to Dissipate Heat

To test the circuits, the Electrical team installed each circuit individually in a robot with a VEX computer, a pair of Fisher-Price motors capable of drawing 30 amps each, and 4 CIM motors capable of drawing 40 amps each. This robot was then run for a five minute interval with five separate ten second intervals, one in each minute, where all motors would draw maximum amperage. A voltmeter with thermocouple would be used at one minute intervals in each test to measure the increase in the temperature of the voltage regulator circuit. The thermocouple was placed on the LM317 component to find the increase in temperature. If the temperature exceeded 100 degrees Celsius, the team would immediately stop the test because the technical document for the LM317 indicated

that the component would fail at 125 degrees Celsius.

In addition to testing the ability of the circuit to dissipate heat, the Electrical Team tested each circuit's ability to continuously deliver the proper current and voltage. This ability was most important for the circuit with the fan attachment, since the fan draws its power from the same supply that is regulated. Two voltmeters were used to measure current and voltage at 30 second intervals.

Results of Continuous Circuit use over Five Minutes

The tests were run with no need to stop because of overheating. Table 1 compares the temperature of the LM317 in each circuit to the time elapsed.

Table 1: Comparison of Circuit Heat Dissipation

Time (minutes)	Plain Circuit (Celsius)	Heat Sink Circuit (Celsius)	Fan Circuit (Celsius)
0	26	26	24
1	42	39	29
2	53	48	33
3	61	54	36
4	65	58	39
5	67	61	40

The robots and circuits performed admirably throughout the stress test with no failures. None of the circuits suffered any damage. Additionally, all three circuits maintained 7.2 volts and 50 milliamps through the duration of the test. With no significant variation, each robot ran to its maximum potential, and each circuit performed its job as expected.

Analysis of Test Results

The data collected confirmed that all three circuits tested could effectively replace the dual-battery system. They all supplied appropriate amounts of current and voltage, even under extreme use, and without overheating. The Electrical Team desires the smallest possible circuit at the lowest expense. With that in mind, the team concluded that the unmodified circuit without a heatsink or fan was optimal.

Printed Circuit Board Development Expenses

With the design finalized, and no need for a fan or heatsink, the circuit can be designed on a printed control board and manufactured by BatchPCB. The design has already been approved and quoted for $1.25 per board. This option will cost less than repurchasing a 7.2-volt battery, which retails for $29.99. Additionally, if Vanden Robotics purchases boards in bulk, in-house technicians can assemble them for resale at a profit. The boards ship within 2 to 3 weeks, but can be expedited to 1.5 weeks for $10 shipping. Purchasing 5 boards would cost just under $10 when shipping is included, but would save $140 in battery replacement costs over the next 2 years. This is because the current inventory of batteries was purchased in December of 2010, and their lifespan is approximately 3 years.

Recommendation to Fund Printed Circuit Board Development

As demonstrated above, the voltage regulator circuit is an excellent replacement for the dual battery system and—if implemented on all five robots—will save Vanden Robotics over $140. The Electrical Team strongly recommends financing the development of printed circuit boards for this voltage regulator circuit, as doing so will reduce costs and enable Vanden Robotics to become a major supplier. Once approved, the circuits can be designed within three days and arrive within a few weeks for installation before the next robotics convention in January. The old batteries can be sold as used or reassigned to other departments. Any batteries not worth reusing should be disposed of at an electronic waste center.

The Electrical Team hopes that this memo provides enough information to help management reach a decision. If there are any questions or suggestions, the team can be reached via email at vandenrobotics.eteam@gmail.com or contacted directly in the offices in the south wing.

SS/pe