Teaching Instrumentation through Solar Car Racing

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Abstract

Solar car racing has been a means of motivating hands-on engineering education through competition among North American higher education institutions. Sunrayce, and now Formula Sun and American Solar Challenge, have tested the abilities of engineering students over the past decade. Proper instrumentation of the vehicle is critical for testing during the vehicle design and for successful racing. As an important part of the solar car team, the instrumentation team not only learns technical skills, but also the soft skills of planning, managing, and working with others to reach a common goal.

Introduction

Focusing engineering education on projects and competitions is a popular approach to giving students experience with real open-ended design problems, teamwork, communication, and leadership[1,2,3,4]. ABET requires engineering programs to demonstrate that their graduates have fundamental knowledge and know how to apply it working in teams. Student teams participating in solar car racing develop not only technical skills, but also communication, project management, and teaming skills. The Center for Advanced Manufacturing and Production (CAMP)[5,6] at the South Dakota School of Mines and Technology promotes engineering education through team-based projects. One of these team projects is the solar car competition.

Sunrayce, patterned after the World Solar Challenge in Australia, has been a biennial competition among North American higher education institutions. Students design, build, and race solar powered vehicles on secondary roads over a ten day period. Recent races have been from Indianapolis to Colorado Springs and Washington D.C. to Orlando Florida. The 2001 race, now called the American Solar Challenge[7], is from Chicago to Los Angeles.

Solar Car Instrumentation

Figure One shows the power system of a typical solar car. Strings of solar cells are connected to peak power trackers (PPTs). The PPT is a dc-dc converter that causes the solar cells to operate at the knee of the current vs voltage characteristic to produce the maximum power. The total array of solar cells on a typical solar car can produce around one kilowatt under best conditions. The power from the solar array charges the battery pack and powers the motor. When there is not sufficient power available from the array, power from the battery pack is used. The drive motor is a high efficiency brushless dc motor.

As shown in Figure Two, a typical instrumentation system acquires data from sensors to measure:

- solar array current, battery current, and motor current,
- voltages of each battery in the battery pack,
- various temperatures and,
- vehicle speed.

From these measurements, estimates of acquired solar energy and battery stored energy must be determined. Team members learn signal conditioning, computer interfacing, data logging, real-time programming, and data display. Data must be displayed to the driver and through the telemetry system. Both road racing (Sunrayce, American Solar Challenge) and track racing (Formula Sun) use telemetry to log and display data in a chase vehicle or in the pit. This data is crucial for making informed decisions during the race.

The South Dakota School of Mines and Technology Solar Motion Team[8] instrumentation system began in 1995 with a commercial data logging system. Over four solar races, the instrumentation system has evolved to a distributed network of sensors and microcontrollers acquiring, processing, and displaying race data to the driver and, over a wireless link, to a strategy team.

Outcomes

An important result is that student team members get real-world assessment of their design by how well their system performs under the demanding conditions of solar car racing. Students have learned through experience that circuits that work well in the lab may not withstand the harsh conditions encountered during competition. Circuits have failed due to overheating, circuits have failed due to vibration, and circuits have failed due to moisture from heavy rain. Packaging, printed circuit boards, connectors, and power distribution must be designed to withstand the harsh conditions encountered in racing. Heat, vibration, and rain must be considered.

The instrumentation team must design to meet safety standards. Strict rules for competition govern the solar car design: (1) size of cars, total photovoltaic cell area, and storage batteries (2) mechanical safety: steering, braking, impact, rollover and (3) electrical safety: isolation, grounding, fusing, signaling, and switching. This gives students experience in meeting strict specifications not often encountered in student projects.

Students have learned that documentation is critical for recording these lessons for use by future team members. Students have published in an IEEE journal [9], in a thesis[10], and in reports for courses[11, 12, 13, 14, 15, 16].

Not only does the instrumentation team learn from this experience, students in Electrical, Computer, and Mechanical Engineering courses learn through examples, laboratory projects, homework, and programming assignments based on the solar car. Freshmen learn through programming assignments to compute energy requirements. Sophomores in introductory circuits learn about voltage and current measurements. Juniors in a mechatronics course learn sensors, signal conditioning, and computer interfacing. Seniors have a capstone design project opportunity.

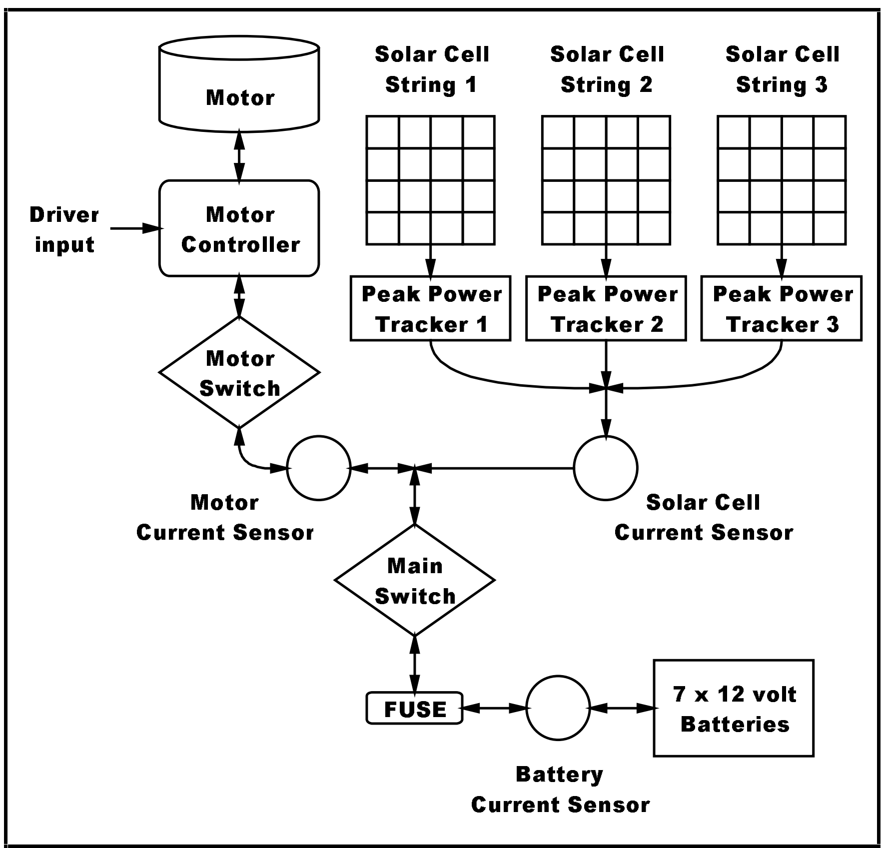

Figure One
Generic Solar Car Power System[10]

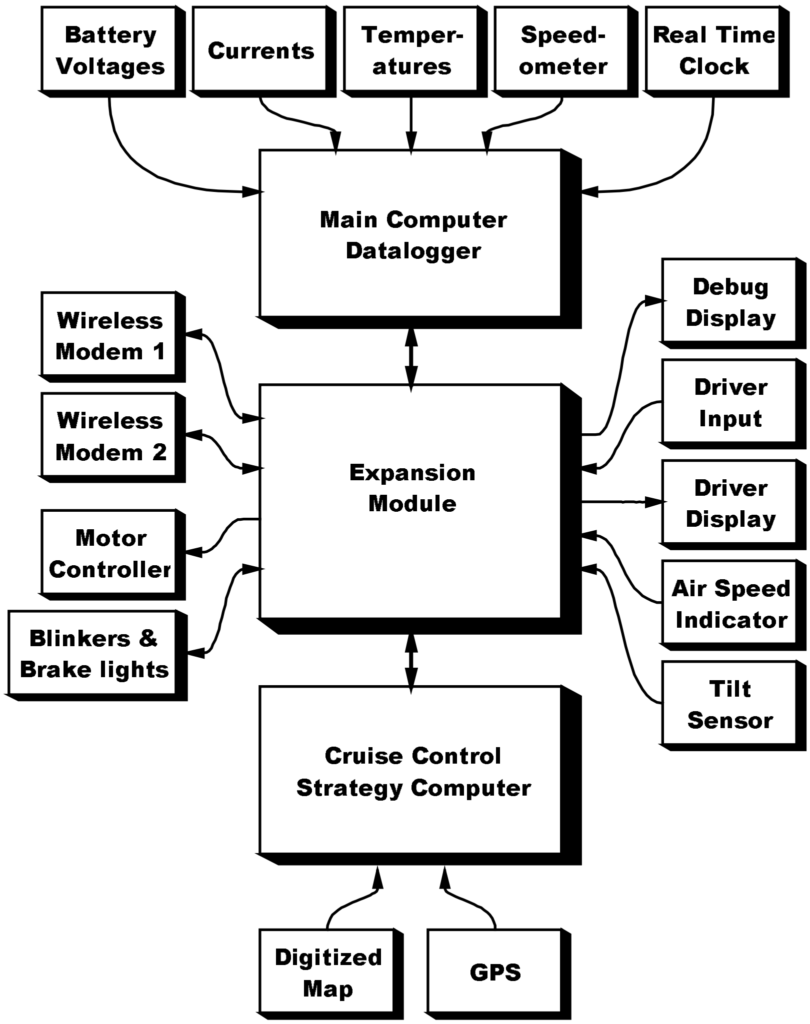

Figure Two
Dakota Sun Instrumentation System Block Diagram[10]

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Biographical Information

MICHAEL J. BATCHELDER
Mike Batchelder joined the SDSM&T faculty in 1974 after completing a Ph.D. in Electrical Engineering from Virginia Polytechnic Institute and working in industry for several years. Mike, a professor in the Electrical and Computer Engineering Department, has enjoyed teaching undergraduate courses for over 25 years. In addition, he has experience with administrative duties as past chair and interim dean and has worked with the South Dakota Governor's Office of Economic Development on many projects including two startup companies. His interests include the hardware and software of embedded computer systems.

DANIEL F. DOLAN
Dan Dolan joined the faculty of the SDSM&T in 1981 after completing a PhD in Mechanical Engineering from the University of Minnesota and a Post Doctoral Fellowship at the University of Duisburg in Germany. He has been actively involved in the teaching of undergraduate courses for almost 18 years. He has taught courses in thermodynamics, dynamics, controls and manufacturing. He enjoys teaching in all of these areas, but especially in vehicle development courses such as *IC Engines* and *Vehicle Dynamics*. He has worked in industry for General Motors and Onan on engine development and at MTS on manufacturing control system development. He has co-authored over 25 technical papers and is the co-inventor on two patents.