EVS27
Barcelona, Spain, November 17-20, 2013

GPRS telemetry system for high-efficiency electric competition vehicles

Alfonso Gago Calderón[1], German Galbeño Ruiz[2], Alfonso Carlos Gago Bohórquez[3]
[1](corresponding author) Fundación Solitec, Dept. I+D, C\ Marea Baja Nº 19 29006 Málaga, alfonso_gago@solydi.com
[2] Siemens AG. Dpt. Supply Chain Management, g.galbeno@gmail.com
[3] University of Malaga, Dpt. Electronics, 2.2.41, acgago@uma.es

Abstract

It has been generated a complete wireless electronic telemetry system for experimental electric competition vehicles. Its purpose is to optimize the processes of monitoring, analysis and evaluation of this type of vehicles designed by multidisciplinary groups of engineers, scientists, professors and students belonging to universities or research centers. Participation in competitions allows testing relevant developments and innovations in this technical field under severe real usage conditions and the system proposed offers a tool for real-time monitoring that is vital to optimize these processes during tests and races.

Keywords: Project-based Education, Electric Racing Vehicles, Telemetry system, Wireless, GPRS

1 Introduction

Electrical competition vehicles are light weight, low power vehicle designed and built exclusively for efficiency racing. These highly technological race cars do not represent a practical means of transportation as: They have only seat one person, have very little cargo capacity, and lack of comforts. However, they do offer an excellent opportunity to develop future technologies that can be applied to practical applications.
Universities and investigation groups put a lot of effort, time and professors and students working for electrics engines in this field:

- new photovoltaic
- hydrogen
- biofuels
- battery charged power systems

This involves design and well as investigation and development. Competition is an activity in which organizations and individuals design, build, and race vehicles that are entirely powered by electrical energy. Prototypes and real test are necessary to verify all the investigation and technology generated around the field of vehicles and the new power systems that are being introduced. And so racing events are increasing in number and getting bigger and more popular all over the world.
The University of Malaga, along with the local municipal government and its energy agency (AGEMA) and several small and medium enterprises and companies located on the surroundings of this university have generated together one of these teams and keep developing complete vehicles with different power supplies and all the necessary technical equipment to optimize these goals.
This paper shows one of the engineering projects developed within this team. It has been developed a telemetry system that allows a comprehensive analysis of the operation mode of the electrical vehicles (EV) both in tests procedures and in real competition. It helps to guide and advise the pilot

This work has been partially done under the project International Campus of Excellence Andalucía TECH in the framework of the Programme International Campus of Excellence of the Educational Ministry of Spain

from the team´s technicians in the team base based on the real time interpretation of these data.
They are generated by an electronic monitoring device that provides the vehicle information obtained in a display and also stores it in a memory unit. Before the development of this work, the team's technical staff could only get this vehicle information as transmitted by voice from the pilot over a radio.

Figure 1: Electric vehicles of the University of Malaga with the previous speech system for data and advice feedback.

This system had several drawbacks:

- It forces the pilot to be aware not only about the performance and an optimal driving but also of reading the vehicle status from the monitoring equipment and sending it to technicians.
- As many the teams use similar communication equipment, transmissions are usually noisy, which usually generate misunderstandings or incomplete information.
- The received information is compiled in a provisional or accelerated way, with a wide range of possibility to generate errors.

In order to solve all of them, it was decided to generate an electronic autonomous telemetry system. This relief the pilot of the transmission responsibility and offers a digital processing tool that provides accurate real-time information.
The system has been developed divided on three main blocks:

- Design an electronic device to obtaining the information generated by the monitoring system and provide all the input and output interface requirements.
- Initialize, generate and keep active a reliable digital communication channel between the car and the telemetry control unit.
- Develop an intuitive software application that receives the car information from the vehicles and process this according to the needs of the vehicle´s technicians in order to ease decisions and planning during and after the race.

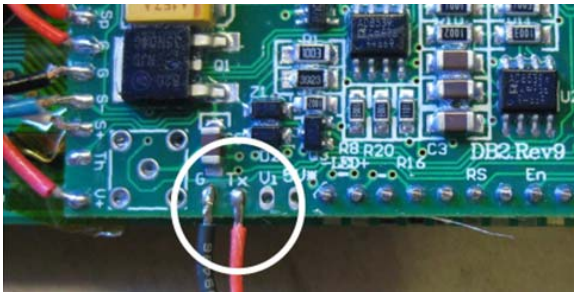
2 Monitor equipment

The data acquisition from the vehicle is done by the device 'cycle analyst'. This is a digital monitor for batteries designed for the requirements of small electric vehicles like ours. It allows measuring both the operating parameters of the power systems and all the dynamic values of the racing electric vehicle with good precision and optimal reliability

It has a serial tab-delimitated ASCII 9600 bauds data channel. After every second emits a packet with the following information:

- Amperes-hours
- Voltage
- Amperes
- Speed
- Distance travelled.

Figure 2: Cycle analyst structure



Ah	V	A	S	D3
3.296	47.62	10.04	15.32	8.9132
3.299	47.49	13.22	16.41	8.9175
3.302	47.43	13.45	17.30	8.9220
3.306	47.85	6.02	17.52	8.9268
3.308	49.36	-1.43	17.17	8.9317
3.307	49.55	-3.69	16.05	8.9365
:	:	:	:	:

Figure 3: Cycle analyst communication chanel

3 Telemetry system

The telemetry system is based on three different functional blocks

3.1 Electronic device for the EV

It has been developed an electronic architecture around an ultra-low power microcontroller (MSP430) from Texas Instruments. Its missions and goals are:

- Fit all the electronic devices of the telemetry system in a compact unit easy to use and control. It must manage its own power supply and all the elements required to work
- Obtain all the battery and motion information offered by the vehicle monitoring system installed
- Encapsulate data within a communications protocol that ensures the robustness of the transmissions and extend the functionality: Commands, equipment address, timestamps,...
- Send these packages generated through the designated wireless communication system
- Manage any information or functional requests that may come from the pilot or the control box to their counterparts
- Interact with the pilot in visual or audible ways such as through LCD screens, LEDs or buzzers

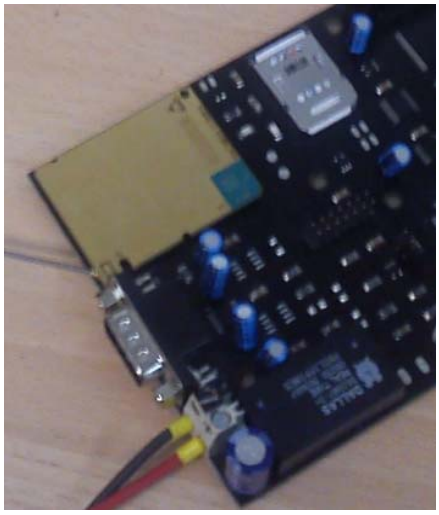


Figure 4: Telemetry electronic system: Electronic controller.

3.2 Wireless communication system

The telemetry system requires a medium distance wireless channel with two main requirements:

- Robustness over the complete distance of the common race circuits
- Security and noise immunity

3.2.1 Technology analysis and selection

In the application development there were analysed mainly two communication technologies:

- Unlicensed band radio frequency (RF)
- Mobile phone operator.

After several tests with 866 MHz RF technology and the experience obtained from other teams in several competitions and meetings it was discarded because of the impossibility of ensuring the communication across all the circuit according to the shape or obstacles founds on the terrain (hills, metal screens advertising ...). Thus, after verifying that all the circuits in which the team has competed have very good mobile coverage along all their tracks, this second technology was the selected option for our system.

Within this wide field the GPRS technology is the specific one chosen:

- It is a very robust and proven option that offers the bigger coverage warranty
- The bandwidth offered exceeds the requirements of our telemetry system.
  - GPRS or 2,5G = 9,6 Kbps (Class 10 y CS-4 hasta 40.0 Kbps)
  - Telemetry system requirement (vehicle → software) = 50 bps
  - Expansion capacity: 9,5 Kbps.

3.2.2 Processor type

It has been selected a Cintereon communication module: The TC-65. It is a GPRS modem with an embedded ARM processor which runs a Java machine. It manages the operation and data flow of the modem. There is a pin compatible communication module from the same family product with a GPS signal receiver incorporated which may provide important additional telemetry information (TC-65i+ module).
This module works as a data channel between the microcontroller and the telemetry software. Between the modem and the microcontroller it is generated a supervision activity to ensure the robustness of the system. Each processor must verify that the other one is active and working properly, otherwise handles its reset and re-start routine.

Figure 5: Telemetry electronic system: TC-65i.

3.2.3 Communication architecture

The modem selected generates a TCP data server identified with a dynamic IP. This is available through a text message to the phone number of the SIM card used in the device and the used to configure the telemetry client software. In this way, many computers can be used to run this application receiving the same data from the vehicle that is running.

3.3 Telemetry software

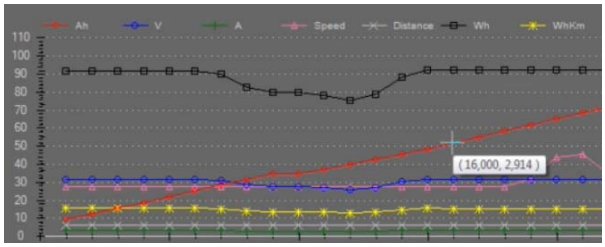
It has been generated a visual and intuitive application that acts as a client of the TCI/IP communication channel generated by the electronic telemetry system placed on the car. Thus it acts as a system server and so allows having several applications running in different computers connected and obtaining the same values.
This application shows all the relevant information and control commands in a common race process divided into 4 functional basic blocks with:

- Configuration options of the application and the wireless data channel used. It allows to get connected to the desired car to be supervised
- Specific relevant data of the pilot driving the vehicle and the shape and any other particular important information about the race circuit.
- Numerical values of the most important technical data of the vehicle on real-time basis.
- Graphical representation window of all the monitored data received during the complete race process.
  This window is the most complex part. It shows all the race data and allows to focus on a specific time window displaying all the measured data or to show only the desired data on each moment. It also generates a file with this information directly exportable to spread sheets or databases.

Figure 6: Telemetry client software application: overview.

The application receives information from the electronic device placed inside the car. The application can calculate new information from these data and show the following information on a screen:

- Energy consumption
- Battery voltage
- Instantaneous power usage
- Speed
- Distance
- Energy efficiency.



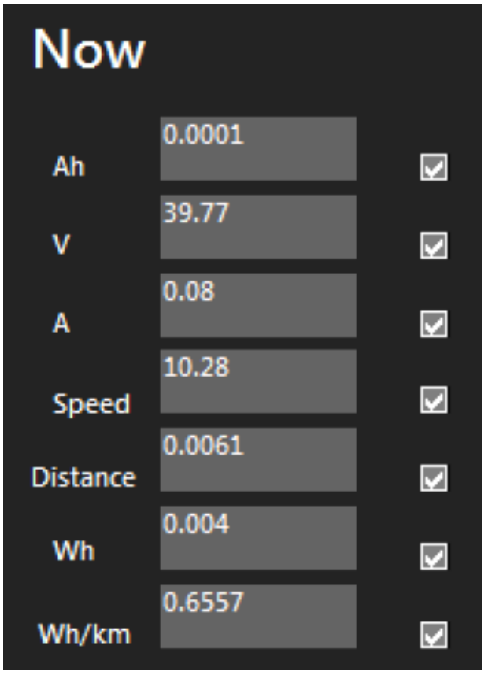


Figure 7: Telemetry client software application: details.

4 Conclusions

It has been designed and generated a complete telemetry system to supervise experimental electric competition vehicle based on an electronic console. This is generated with a low-power electronic processor, a GPRS modem communication channel that generates a TCP / IP server and a client remote monitoring software application.

We have built two prototypes that have been tested under the expected conditions of use both on closed test road and on competition circuits. The total cost of this device (below € 250 for prototypes) and operating expenses are low and acceptable within the budgets of this kind of projects.

These tests covered:

- Robustness
- Coverage
- Connectivity
- Functionality of the system with optimal results and the satisfactory opinion offered by pilots, engineers, designers and technical crew of the racing team.

Acknowledgments

We wish to express our sincere gratitude to all the students, professors and to all the technical and professional collaborator who built up the EV racing team from the University of Malaga.

References

[1] B. Rogow, *Suntrakker - A student-designed solar vehicle*, Electrical Insulation Conference, 1997, and Electrical Manufacturing & Coil Winding Conference. Proceedings, 22-25 Sep 1997, 694-697, doi: 10.1109/EEIC.1997.651281

[2] R. Mangu et. Al., *Design, Development and Optimization of Highly Efficient Solar Cars: Gato del Sol I-IV*, Green Technologies Conference, 2010 IEEE, 15-16 April 2010, 1-6,. doi: 10.1109/GREEN.2010.5453800

[3] Suita, Y. et. Al., *Driving Performances of Solar Energy Powered Vehicle with Novel Maximum Power Tracking Control for a Solar Car Rally*, Industrial Technology, 2006. ICIT 2006. IEEE International Conference on, 15-17 December 2006, 1218-1223,. doi: 10.1109/ICIT.2006.372463

[4] De-jian, X. I. A. Overview on Rese]arch in Electric Vehicles [J]. *Energy Technology and Economics*, 2010, Vol. 7.

[5] Chang, H., Farooqui, F., & Mann, W. Wireless Telemetry System for Solar Car. *Dept. Elec. Eng., Georgia Institute of Technology, Atlanta, Senior Design Project*, 2010.

[6] Sternal, K., Cholewa, A., Skarka, W., & Targosz, M. Electric Vehicle for the Students' Shell Eco-Marathon Competition. Design of the Car and Telemetry System. En *Telematics in the Transport Environment*. Springer Berlin Heidelberg, 2012. p. 26-33.

[7] Pearce, J. Electric Vehicle Telemetry. Honour thesis, The University of Western Australia, October 2010.

[8] Talvitie J.P. et al. Designing an energy measurement system for an electric vehicle competition - From a student project to a successful race. Instrumentation and Measurement Technology Conference (I2MTC), 2013 IEEE International. 6-9 May 2013. Pp. 528 – 532

[9] McCarthy, L., Pieper, J., Rues, A., & Wu, C. H. Performance monitoring in UMR's solar

car. *Instrumentation & Measurement Magazine, IEEE*, 2000, vol. 3, no 3, p. 19-23.

[10] Ersoz, E. *Development of a racing strategy for a solar car*. 2006. Doctoral Thesis. MIDDLE EAST TECHNICAL UNIVERSITY.

[11] Hilliard, A., & Jamieson, G. A. Winning solar races with interface design. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 2008, vol. 16, no 2, p. 6-11.

Authors

Alfonso Gago Calderón received the M.S. (best academic achievement), and Ph.D. degrees in Industrial Engineering in 2002 and 2010, respectively, and the M.S. degree in audiovisual systems in 2010, all from the University of Málaga, Spain.
From 2003 he is the director of the R&D department of SOLITEC, Spain.
His current research interests include LED Lighting, Large Audiovisual Systems and Electric Vehicles.

Germán Galbeño-Ruiz received the M.S. degree in industrial engineering in 2012. He has belong to the electric vehicles racing team of the University of Malaga and have developed part of its telemetry system in his final degree project (evaluated with honors). From 2012 he is working as an engineer for Siemens AG in the department of Supply chain Management in Germany.

Alfonso Gago-Bohórquez received the M.S., and Ph.D. degrees in physics from the University of Seville, Spain, in 1974 and 1979 respectively.
From 1975 to 1988, he joined the University of Seville as an assistant professor in Physics and Electronic Engineering.
Since 1989, he has been a professor of electronic and computer engineering with the Department of Electronics of the University of Málaga, Spain, where the heads a research group on Electronic Design.
His current research interests include photonic and biomedical systems..