Center for Embedded Systems (CES)
Request for Proposals Template – YEAR 8

DUE: FRIDAY, APRIL 15, 2016, by 11 p.m.

TITLE:	Power-over-Communication approach for integrating remote sensors to motor drives.				
PI:	Constantine J. Hatziadoniu	**EMAIL:**	hatz@siu.edu	**TEL:**	(618) 453-7036
DEPT:	ECE	**SCHOOL:**	SIUC		

ABSTRACT: (250 or fewer words)

In many industrial applications involving motor drives, the physical sensors are located away from the motor controller. As a result, lengthy multi-conductor cables must be used to transmit the power necessary to supply the sensor electronics and the analogue signals from the sensor output to the controller location. This project proposes to eliminate this heavy wiring between sensors and controller by using an approach equivalent to Power over Ethernet (PoE) to transmit sensor output signals as well as to power sensor devices. First, the sensor outputs are filtered and integrated into an SoC. The SoC provides functions for each sensor for additional signal conditioning. Second, the digital representations of the sensor outputs are combined and transmitted to the controller site using techniques based on PoE and suitable communication protocols. The main challenges of the project are to provide the appropriate communication arrangement so that the motor stability is not affected and, also, provide suitable design of the sensor conditioning system under the restriction of a limited space. The proposed project is expected to be of a particular benefit to the aviation industry by reducing weight and EMI.

PROBLEM:

The project proposes to eliminate heavy wiring between sensors and controller typically necessary in drive applications by using Power-over-Ethernet (PoE) or equivalent approach to transmit sensor output signals as well as to power sensor devices.

RATIONALE:

In many industrial applications involving motor drives, the physical sensors are located away from the motor controller. As a result, lengthy multi conductor cables must be used to transmit (a) the power necessary to supply the sensor electronics and (b) the analogue signals from the sensor output to the controller location. Hence, in these systems, the sensor outputs are conditioned at the controller site. This provides certain advantages including the possibility of reducing the size of discrete components by integrating sensor conditioning and control functions. In recent projects funded by CES, the PI has used SoC technology to integrate advanced motor drive control functions with positioning and speed sensors. However, in certain environments, such as in airplanes, the additional cables contribute in the overall weight. In addition, EMI and other noise interference become an issue.

CURRENT SOLUTION:

Presently, the sensor conditioning is implemented along with the controller functions using mostly discrete components. This integration takes place at the controller location. Fig. 1 shows the system layout in the present state for an avionic application. Three sensors are used, a position resolver, a displacement sensor via a linear variable differential transformer and a temperature sensor. These are physically located in the sensor box. The sensor box is, in turn, located away from the motor controller and the power electronic converter. Presently, therefore, a cable with numerous wires is necessary to transmit the sensor outputs to the controller, where they will be conditioned. For example, for the above three sensors, 12 wires will be necessary.

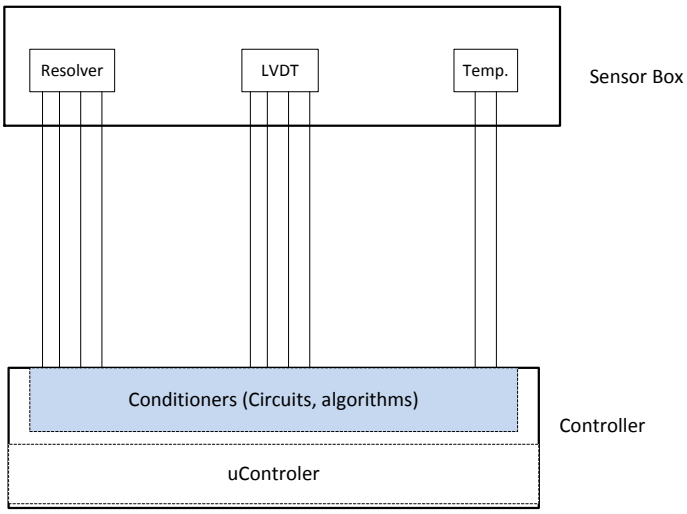

Fig. 1. Sensor/controller connection in the present state.

INADEQUACY:

The main drawbacks of the present technology to the aviation industry is the weight and cost added by the wires and the risk of EMI given that the wire cable must route through other noisy processes.

PROPOSED SOLUTION:

The proposed solution consists in using a PoE equivalent approach [1-3] in order to connect the sensor output to the controllers and also power the sensors. The proposed method is explained in Fig. 2. With reference to the figure, first, the sensor outputs are filtered and integrated into an SoC. The SoC provides functions for each sensor for additional signal conditioning. Second, the digital representations of the sensor outputs are combined and transmitted to the controller site using either PoE or an equivalent scheme along with suitable communication protocols. Fig. 3 shows the system configuration at the site of the controller. The main challenges of the project are to provide the appropriate communication arrangement so that the motor drive stability is not affected and, also, provide suitable design of the sensor conditioning system under the restriction of a limited space.

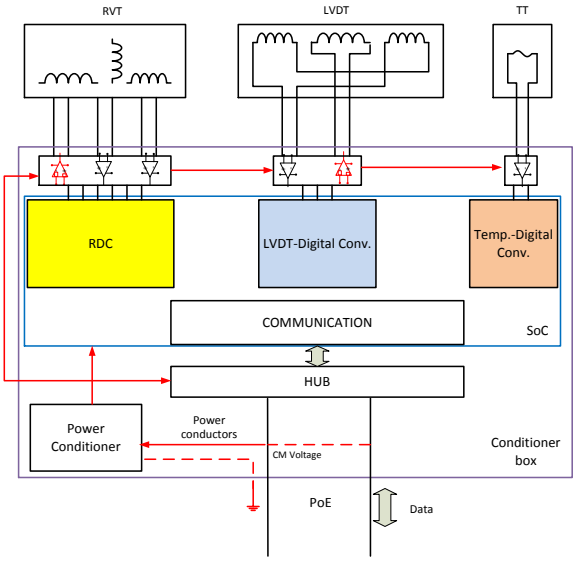

Fig. 2. Proposed sensor integration using SoC and PoE.

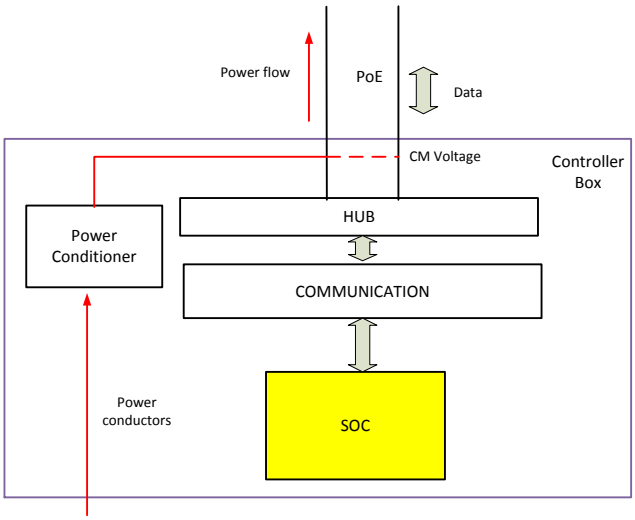

Fig. 3. Proposed controller implementation using SoC and PoE.

NOVELY:

The proposed project will use PoE or an equivalent approach to replacing the complex long wiring between sensors and controller. In addition, it will significantly reduce the sensor conditioning size using the SoC technology which represents a significant gain in aerospace applications.

POTENTIAL BENEFITS TO INDUSTRY MEMBERS:

The proposed project is expected to be of a particular benefit to the aviation industry by reducing sensor conditioning size, cable weight and EMI.

DELIVERABLES:

The deliverables will include:
(a) integration of sensors into SoC: sensor models, SoC programing.
(b) algorithms for the communication between sensors and controller.

TIMELINE / MILESTONES (PER QUARTER):

August-December: literature review and development of suitable models and algorithms.
Jan-May: Developing SoC program.

TECHNOLOGY TRANSFER:

The algorithm developed will be directly transferred onto the SoC at SIUC site.

BUDGET:

The project requests $25k for the entire duration. The funds will support a graduate student and half of a month salary for the PI.

BIBLIOGRAPHY: (ATTACH IN IEEE CONFERENCE OR JOURNAL FORMAT)

1. C. Heller; E. Heidinger; S. Schneele; W. Fischer; P. Klose, *Power-over-Ethernet for avionic networks*, Digital Avionics Systems Conference (DASC), Munich, Germany, 2010 IEEE/AIAA 29th
2. Paule Lee, Powering: the ability to provide power over the Ethernet is crucial to the adoption of the communication protocol. IET Computing and Control Engineering Dec/Jan 2006/07.
3. Q. Gao *et al*., "Design and implementation of LED intelligent lighting system based on the technology of PoE," *The 27th Chinese Control and Decision Conference (2015 CCDC)*, Qingdao, 2015, pp. 2628-2633.

PI INFORMATION: (ATTACH 2-PAGE CV):

CONSTANTINE J. HATZIADONIU, Professor, hatz@siu.edu
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Carbondale, IL 62901-6603

Education

Diploma in Electrical Eng., University of Patras, Greece, 1983
Ph.D. in Electrical Eng., West Virginia University, Morgantown, 1987

Professional Experience

- Professor of Electrical and Computer Engineering, Southern Illinois University Carbondale. Sept 1987-present.
- Teaching and Research Assistant. Department of Electrical Engineering, West Virginia University, Morgantown. August 1984-1987.
- Consulting engineer, Greece. August 1983-1984.

Research Interests

Power electronics, Energy harvesting devices, wind and photovoltaic energy systems, power system modeling and simulation; power system control and protection.

Recent Publications.

Nezar Abou Qamar, **C.J. Hatziadoniu**, Haibo Wang, "Speed error mitigation for a DSP-based resolver-to-digital converter using autotuning filters", IEEE Trans. On Industrial Electronics, Vol. 62-2, Feb 2015, pp 1134-9.

Hany A. Abdelsalam and **C.J. Hatziadoniu**, "A Robust Wide Area Controller of Multiple FACTS for Damping Oscillations in Multi-Area Power System Using the H∞ Method", Power System Conference 2011 PSC11, March 15-18, 2011 at Clemson University, Clemson, SC, USA.

A. Albanna and **C.J. Hatziadoniu**, 'Harmonic Modeling of Hysteresis Inverters in the Frequency Domain', IEEE Trans. on Power Electronics, Vol. 25, No 5, May 2010, pp.1110-4.

Ahmad Albanna, **C.J. Hatziadoniu**, "Harmonic Modeling and Analysis of Multiple Residential Photo-Voltaic Generators", Power and Energy Conference, University of Illinois Urbana-Champaign, February 2010.

Ahmed Albanna, **C.J. Hatziadoniu**, "Harmonic Modeling of Three-Phase Neutral-Point Inverters", Proceedings of the 2009 North American Power Symposium, Mississippi State University, Starkville, MS, Oct 4-6, 2009.

Ahmed Albanna, **C.J. Hatziadoniu**, "Harmonic Modeling of Single-phase Three-level Hysteresis Inverters", Proceedings of the 2009 North American Power Symposium, Mississippi State University, Starkville, MS, Oct 4-6, 2009.

C.J. Hatziadoniu, N.B. Harp, and A.J. Sugg, "Finite-Element Models for Open-Air Power Lines in Broadband PLC", IEEE Trans. On Power Delivery, Vol. 21, No. 4, Oct. 2006, pp. 1898-1904.

F. Pourboghrat, F. Farid, C.J. **Hatziadoniu**, M. Daneshdoost, F. Mehdian, M. Lotfalien, "Local Sliding Control for Damping Inter-Area Power Oscillations", IEEE Trans. On Power Systems, PES 19-2, May 2004, pp. 1123-34.

G. Chang, **C.J. Hatziadoniu**, W. Xu, P. Ribeiro, R. Burch, W.M. Grady, M. Halpin, Y. Liu, S. Ranade, D. Ruthman, N. Watson, T. Ortmeyer, J. Wikston, A, Medina, A. Testa, R. Gardinier, V. Dinavahi, F. Acram, P. Lehn, "Modeling Devices with nonlinear Voltage-current Characteristics for harmonic studies", IEEE Trans. On Power Delivery, Vol. 19, No. 4, Oct. 2004, pp. 1802-11.

Synergetic Activities.

- "Pilot Study of Energy Harvesting Devices towards the Development of a Prototype", (PI C.J. Hatziadoniu, Co-PI Tsuchin Chu and Fran Harackiewicz), NSF, I/UCRC for Embedded Systems August 2012-August 2013.
- "Resolver Sensor Conditioning Size Reduction", (PI C.J. Hatziadoniu, Co-PI W. Haibo), NSF, I/UCRC for Embedded Systems, August 2012-August 2013.
- "Distribution System Modeling for Power Line Communication", Research grant, AMEREN-UE, 2001-2002.
- "Software for the optimum operation and planning of high-data rate PLC Systems", Research grant, AMEREN-UE 2003-04.
- "Workstation Computer Program for Insulation Coordination of ac and dc Substations"
- Research grant (EPRI 1989-1992), RP 2323, with G.D. Galanos and M. Daneshdoost.
- "Advanced Voltage Systems", Research grant (EPRI 1990-1992), RP 4000-22, with G.D. Galanos and F. Pourboghrat.
- "Faraday's Law Electric Machine Laboratory", Equipment grant (NSF 1991), with G.D. Galanos, V. Feiste and M Daneshdoost.

Collaborators and Other Affiliations.

Collaborators: D. Takach, Ameren UE, Saint Louis, Missouri.
Graduate Advisor: Dissertation Advisor: G.D. Galanos, Department of Electrical and Computer Engineering, SIUC.
Thesis and Dissertation Advisor (recent): A. Albana (PhD), H. Ahmed (PhD), Dler Dler (MS), H. El-Hadji (MS), D. Schleeper (MS).

I/UCRC Executive Summary - Project Synopsis		Date:
Project Title:	**Power-over-Communication approach for integrating remote sensors to motor drives.**	
Center/Site: SIUC		
Principle Investigator: Constantine J. Hatziadoniu		**Type: (New or Continuing)** New
Tracking No.: (CES office to input)	**Phone : (618) 453-7036**	**E-mail : hatz@siu.edu**
		Proposed Budget: $25,000

Abstract: (250 words max In many industrial applications involving motor drives, the physical sensors are located away from the motor controller. As a result, lengthy multi-conductor cables must be used to transmit the power necessary to supply the sensor electronics and the analogue signals from the sensor output to the controller location. This project proposes to eliminate this heavy wiring between sensors and controller by using an approach equivalent to Power over Ethernet (PoE) to transmit sensor output signals as well as to power sensor devices. First, the sensor outputs are filtered and integrated into an SoC. The SoC provides functions for each sensor for additional signal conditioning. Second, the digital representations of the sensor outputs are combined and transmitted to the controller site using techniques based on PoE and suitable communication protocols. The main challenges of the project are to provide the appropriate communication arrangement so that the motor stability is not affected and, also, provide suitable design of the sensor conditioning system under the restriction of a limited space. The proposed project is expected to be of a particular benefit to the aviation industry by reducing weight and EMI.

Problem: The project proposes to eliminate heavy wiring between sensors and controller typically necessary in drive applications by using Power-over-Ethernet (PoE) or equivalent approach to transmit sensor output signals as well as to power sensor devices.

Rationale / Approach: In many industrial applications involving motor drives, the physical sensors are located away from the motor controller. As a result, lengthy multi conductor cables must be used to transmit (a) the power necessary to supply the sensor electronics and (b) the analogue signals from the sensor output to the controller location. However, in certain environments, such as in airplanes, the additional cables contribute in the overall weight. In addition, EMI and other noise interference become an issue. It will be, therefore, beneficial to, particularly, the aviation industry, if the problem can be addressed by reducing sensor conditioning size and combining power and communication signals.

Novelty: The proposed project will use PoE or an equivalent approach to replacing the complex long wiring between sensors and controller. In addition, it will significantly reduce the sensor conditioning size using the SoC technology which represents a significant gain in aerospace applications.

Potential Member Company Benefits: The proposed project is expected to be of a particular benefit to the aviation industry by reducing sensor conditioning size, cable weight and EMI.

Deliverables for the proposed year: The deliverables will include:
(a) integration of sensors into SoC: sensor models, SoC programing.
(b) algorithms for the communication between sensors and controller.

Milestones for the proposed year: August-December: literature review and development of suitable models and algorithms.
Jan-May: Developing SoC program.

Progress to Date: **THIS SECTION TO BE UPDATED IN JANUARY**

Estimated Start Date: August, 2016	**Estimated Knowledge Transfer Date**: May, 2017