Sensor Telemetry Using Bluetooth Technology

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Abstract-- A traditional method for transferring data in rotating mechanisms has been the slip ring, but these are not viable inside pistons due to size, the associated cabling, and the requirement of one slip ring per parameter. A mechatronic data acquisition system is developed whereby signal conditioning is performed by the sensor and the signal passed to a Bluetooth transmitter module for wireless telemetry to a Bluetooth receiver located in very close proximity, connected to an external host PC. The Data Acquisition (DAQ) Bluetooth module integrates a microcontroller that reads the conditioned thermocouple signal and performs any other DAQ functionality required. The microcontroller firmware includes a server that collates all DAQ data for transmission via Bluetooth to the host PC for display via a client interface. This Short Distance Telemetry (SDT) system is a substitute for slip rings and their associated cabling. A slip ring also transfers power, but this cannot be achieved with the SDT system, therefore an independent power supply is required. The power supply consists of a rotor incorporating NdFeB magnets and a wire wound stator. As the shaft rotates the rotor induces an AC voltage into the stator. A rectifying circuit converts the AC voltage into a regulated DC output voltage that drives the signal conditioning and embedded Bluetooth circuits.

Index Term-- Short Distance Telemetry, Bluetooth.

1. INTRODUCTION

Telemetry can refer to data transfer over any media, but typically refers to wireless communications. A basic telemetry system consists of a measuring instrument or detector, a medium for sending the transmission, a receiver, and an output device that records and displays data. Many of today’s telemetry systems are built from common, off-the-shelf, elements configured to meet specific application requirements. A transducer obtains the monitored signal and converts the value into an electrical impulse ready for transmission. But telemetry applications which support large numbers of measurands are too costly and are impractical when used with separate transmission channels for each measured quantity (such as pressure, speed, and temperature). Measurements are formatted or multiplexed and transmitted as a single data stream. At the receiver, the data stream is separated into the original measurement components for analysis.

This paper describes a low cost, low power, embedded wireless transmission system for data acquisition, signal processing and display of thermocouple temperature on a PC host. A sensor circuit and wireless Bluetooth module form the basis of the telemetry system (Figure 1). A PC host can be configured as a Bluetooth receiver and / or a system development environment.

![Telemetry System Block Diagram](image)

Fig. 1. Telemetry System Block Diagram

2. SHORT DISTANCE TELEMETRY

Short Distance Telemetry is a system to capture sensor output signals and transmit data over a short distance, of up to a few centimetres, to a receiver. The system comprises of a sensor and signal conditioning, which may be combined as a smart sensor (Hierold et al 1999), an encoding system and transmitter, an antenna and a power source. The receiver is connected to a host, usually in the form of a PC, that performs analysis and displays results. As encoding occurs before transmission, the sensors can be either analogue or digital.

SDT is an important telemetry method because it can be used in small confined spaces or harsh environments that were previously inaccessible. With the use of micro and nano technology, the systems can be modular, compact and take advantage of the low power and low voltage requirements of these technologies. Embedded systems (Serra et al 2007) or integrated ‘systems on a chip’ (Harpster et al 2002, Hierold et al 1999, Van Helleputte et al 2008) are low cost and low weight, eliminate cables and use wireless radio technology (Valdastri et al 2008). Power sources available include Inductive coupling (Catrysse et al 2004), MEMS (Stephen 2006) or rechargeable batteries, and are determined by application for suitability.

Applications for these systems vary from industrial to medicine. Industries such as aerospace, automotive (Wiczynski et al 1996) and civil engineering (Hughes et al 2006) use telemetry for data acquisition or monitoring of rotating, stationary or mobile applications, whilst medical applications include monitoring of physiological functions from joint movement (Claes et al 2002) to electrocardiogram pulses (Lapray et al 2008, Lin et al 2008). Data acquisition systems can vary from single or multiple channel sensors utilising Bluetooth networks, to single function sensors utilising low speed ZigBee transmission. Although the PC is the most common host for the receiver, utilising the USB port; with suitable software development, PDAs (Yea et al 2008) or mobile phones can act as receivers.

3. METHODS OF TELEMETRY

L-Link linkage carry wires, allowing thermocouple wires to be routed from piston to instruments outside the engine (Furuhama, and Enomoto, 1973). The Contact point method (Takamatsu, and Kanazawa, 1999) the sensor system is connected to a fixed contact arm embedded within a moving...
component. At the extent of its travel, a connection to a contact point, thereby completing a data path for data to be transmitted, via a lead wire for signal conditioning and processing. The induction method (Kato et al 2001) consists of a stationary primary coil and a moving secondary coil connected to the sensor system. Data transmission takes place only during coupling of the coils. The primary coil also provides power to the sensor system. In an Infra red system (Barna et al 1991), output from a sensor or transducer is transmitted by an infrared light-emitting-diode that converts voltage to light. A phototransistor receiver converts light to voltage or current. The LED and phototransistor must be in line of sight with no obstruction between them. Wireless telemetry transmits data wirelessly to a receiver. These systems may be optimised to transmit over large distances, such as WiFi, or optimised for low power consumption and short distances, such as Bluetooth or ZigBee.

4. PROTOTYPE

The proposed prototype method connects small output signal transducers such as thermocouples or strain gauges to an amplifier sensor that reads the transducer and performs signal conditioning to produce either an analogue voltage output or 16 bit digital value output. This signal is input to an embedded microcontroller that performs analogue to digital conversion on the analogue input or stores the data value of the digital input, and then transmits the data value over a Bluetooth radio to a Bluetooth adapter connected to a host.

4.1. Hardware

The telemetry system is powered by an induction power generator. The stator coil is formed adjacent to a permanent magnet rotor, formed around a shaft. The rotating crankshaft induces current and voltage in the stator, which is rectified, filtered and regulated to supply the sensor and embedded Bluetooth module with the required 5v supply. Figure 2 shows the rectified AC supply voltage amplified by a step-up converter and driving a transducer sensor (Analog Devices AD595). Figure 3 shows a digital thermocouple amplifier (Maxim MAX6675) connected to the Bluetooth DAQ module (www.flexipanel.com).

Figure 4a shows the average voltage output from a USB DAQ device (www.ni.com) acquiring analogue data from a thermocouple amplifier sensing a heat source. The Analog devices AD595 amplifier produces 10mv /°C, which equates to 213°C for a voltage of 2.13V.
Figure 4b shows the display for the ADC testing of an analogue input for a signal connected to the Toothpick Bluetooth DAQ module.

4.2. Software

Software development comprises of a Microchip C compiler to create the required hex file for upload to the embedded microcontroller. Flexipanel Designer (www.flexipanel.com) creates the custom user interface and C source code that describes it. This source code and other required files are then compiled into the hex file. This hex file is converted into a flexipanel servicepack and uploaded wirelessly to the PIC18LF6722 target microcontroller (www.microchip.com). Alternatively, the custom interface can be directly uploaded wirelessly from Flexipanel designer.

5. DATA ACQUISITION

When a sensor reads a type K thermocouple transducer, a non linear voltage output, caused by the Seebeck effect, is produced. The thermocouple has to be connected as close as possible to the sensor and the ambient temperature at this connection point (isothermal block) is used to calculate Cold Junction Compensation for the thermocouple temperature. Lookup tables or polynomials can then be used to calculate the actual thermocouple temperature.

The Seebeck coefficient for type K thermocouple is approximately 40 µV/ °C at 300 °C and would produce an output of approximately 12 mV at 300 °C. The AD595 thermocouple amplifier sensor performs signal amplification (x 247.3), applies low pass filtering to remove mains frequency signals, performs Cold Junction Compensation and outputs an analogue voltage of 10mV/°C that represents the thermocouple temperature. The voltage output is passed to an analogue input pin of a Microchip PIC18LF6722 microcontroller that performs 10 bit Analogue to Digital Conversion. The AD595 reads voltages up to 300°C at 5v input supply. A digital thermocouple amplifier (MAX6675) also incorporates signal conditioning and CJC, but the output is a digital value of the temperature which is read by the microcontroller SPI interface. The thermocouple temperature is then transmitted via Bluetooth to the Bluetooth adapter on the PC host for display on a client interface.

The client interface can display the received data via a custom designed interface, as a line plot (Figure 5a), or as data values that can then be saved to file (Figure 5b).

6. DISCUSSION AND CONCLUSION

A generic mechatronic DAQ system is developed using Bluetooth wireless transmission to eliminate hard-wired connections such as slip rings. A wireless system has none of the wear and tear or fatigue disadvantages of the mechanical systems or the line of sight necessity of optical systems.

The system requirements are a combination of analogue and digital signals that read temperature values in harsh environments or signals from rotary devices, a low voltage power generator that eliminates cabling and drives 3v – 5v devices and ease of source coding and microcontroller programming. The process of development is to develop software processing functions, create interfaces, create firmware and program the microcontroller wirelessly.

The choice is made whether to buy or build the system. A built system enables custom design of the system, Inclusion of latest technology and re-use of any previous development, but incurs costs in development time, tooling, and the requirement of in-house and technical expertise. A purchased system has the advantages of short development period, harnessing latest technologies, access to domain expertise and minimised risk, but incurs high purchase cost for a system that may not be optimised for the required task and may be locked to a proprietary system.

The decision is to build the physical system with COTS components and develop the firmware in-house with freely available manufactures development suites. The hardware comprises of individual components to build a custom system. The software components include a firmware development suite for the target microcontroller using C or assembler, a data acquisition interface designer, a wireless firmware uploader, and a low cost firmware programmer.
The Microsoft Bluetooth stack is employed to avoid being tied to proprietary Bluetooth stacks, which may limit the type of Bluetooth components available for the system. Use of the Microsoft Bluetooth stack also facilitates installing the DAQ system on a different PC without having to provide a proprietary stack. Bluetooth is available in a large number of diverse applications and commercial solutions and has the advantage of being low power and supporting scalable ad hoc networks. It can be installed in restricted areas, and is robust to noise interference and harsh environmental conditions.

Flexibility of the system allows for many applications to use same hardware driven by either generic or bespoke firmware which is uploaded wirelessly from a host or on site with a portable programming device.

The modular design of the system allows system components to be located in very close proximity, eliminating the need for cabling, or for processing modules to be located away from harsh data acquisition locations and has the advantage of lower installation costs and reduced maintenance costs.

REFERENCES


