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Acoustic Emission Sensor Networking System (AE-SNS)

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Abstract

Recent advances in embedded systems and associated software tools have given a new dimension in the development of miniature intelligent sensor networking approach to develop state of the art NDT instruments. A new concept is realized to develop multi channel modular acoustic emission system suitable for field applications such as structural integrity assessment.

Conventional acoustic emission systems available today are prone to noise pick-ups due to lengthy cables from electrical disturbances which generate surges and transient disturbances to corrupt the real time signals coming from AE sensors. The concept of intelligent sensor networking includes dedicated signal conditioning filter circuits with associated embedded hardware using latest CPLD devices. The integrated approach eliminates noise at the source level itself, thus enhancing the signal to noise ratio for correct interpretation of the AE signals.

Recent advances in wireless data transmission enables to transfer the data to the cluster head of the sensor networking system. Each cluster head is capable of grouping certain number of nodes where a node is a dedicated Data Acquisition System with head on AE sensor hardwired TCP/IP Protocol. The information from the cluster head is transferred to the dedicated server. Multiple clients are allowed to be connected to the server using standard networking facility for data monitoring, presentation and analysis.

Keywords*:* *Cluster head, Acoustic emission, Access point, Sensor networking, Sensor node*

1. Introduction

A new emerging trend in instrument design has led to sensor networking approach for signal conditioning, event detection, data acquisition, and wireless data transmission and networking hardware. In this design a multi-node AE sensor networking system has been realized. This design is modular in approach and various subsystems are discussed in detail in this paper. This approach enhances signal to noise ratio, immune to external noise and avoids lengthy cable connection which are prone to noise pick-ups thus misinterpreting the AE data. A source location algorithm is also developed for linear and planner source locations. All the standard acoustic emission parameters required for analysis are decoded by dedicated hardware for each node.

2. Design Philosophy

AE sensor networking design philosophy with respect to hardware is dedicated single nodal hardware integrated with head on AE sensor for parametric extraction using micro-controller and CPLD based design. The unique feature of this design is miniature in size and operated on battery power supply. The other modules include access point (cluster head) connected to the various clients to the external world. The software is built using dedicated interrupt driven real time operating system to handle various task associated in the nodal hardware. Standard TCP/IP hardwired protocol is used to realize networking facility.

2.1. Hardware Design and Implementation

2.1.1. Sensor Node Hardware

Each sensor node comprises acoustic emission sensor, preamplifier, AE signal conditioning module. The AE signal conditioning module includes 60dB programmable gain post amplifier, hardware circuits to decode various AE parameters, mixed signal microcontroller (8051F120), CPLD (CY37000) and WIZnet networking module for wireless data transmission.

a. Preamplifier Module

The preamplifier module has a fixed gain of 40 dB is connected to either broad band or narrow band AE sensor as signal input. This pre-amplifier is a charge coupled amplifier having moderate gain, high bandwidth, high CMRR and excellent signal to noise ratio. The other unique feature of this design is to match high impedance of sensors to low impedance of signal cable. (typically 20K ohms to 50 ohms). Pluggable passive band-pass filter design has been incorporated when the amplifier is connected to resonant type of AE sensors to enhance signal and to attenuate unwanted noise.

b. AE Signal conditioning module

The AE signal conditioning card has a dedicated hardware design including 60 dB programmable gain amplifier, unique hardware design to extract various standard acoustic emission parameters like count rate, cumulative counts, event rate, cumulative events, rise time, event duration, counts / event, peak amplitude, RMS and external parameters. The hardware 16 bit counters for cumulative counts, cumulative events, rise time, event duration and counts per event are implemented in CPLD. In addition, CPLD design also provides re-triggerable mono-shot circuit using standard counters for detecting event duration and rise time timings. The digital multiplexer and decoding inside the CPLD interfaces these signals to 8-bit mixed signal microcontroller's data bus for digital data transfer. This card also houses 8-bit mixed signal microcontroller having 8 –channel analog multiplexer, programmable gain amplifier, 12-bit successive approximation A/D converter having sampling rate of 100kps for acquiring various analog signals like peak amplitude, RMS value and four external parameters. The other circuits include 12-bit D/A converter to generate threshold reference. The AE signals crossing the threshold value generates the acoustic emission clock. This mixed signal microcontroller has internal RAM of 256 bytes and 128 KB of flash memory. In addition this device supports 8KB external RAM. It has 8 ports for I/O operation. The planer source location algorithm can be implemented using minimum three sensors. The arrival time of the AE signal to three different AE sensors from the AE source is measured using three timers which is in the microcontroller. From these timings the exact defect location is computed.

c. WIZnet module

WIZnet module (Fig. 2) is a network module that includes W3100A (TCP/IP hardwired chip), Ethernet PHY (RTL8201BL) RJ45 Jack with other glue logics. It supports 10 X 100 base TX,

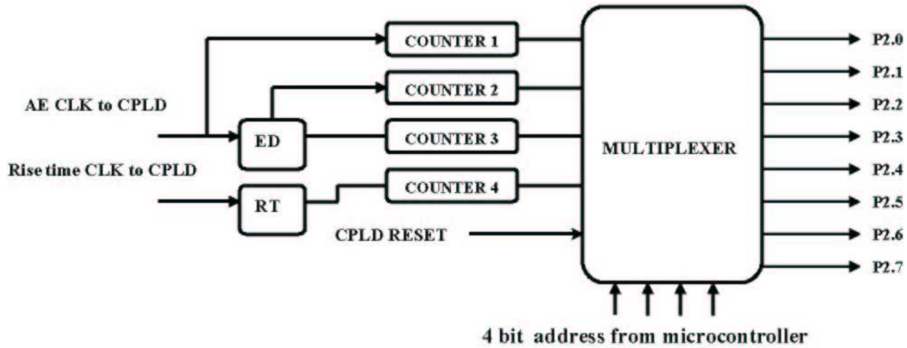

Figure 1

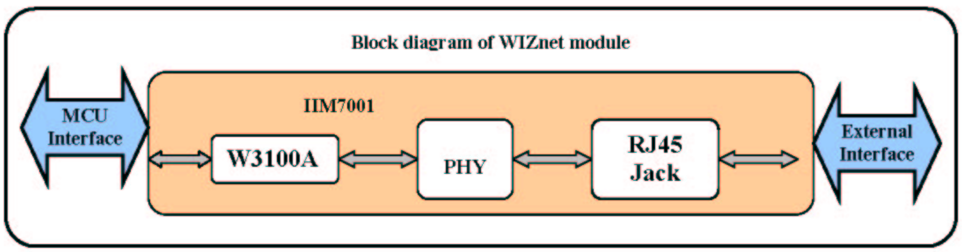

Figure 2

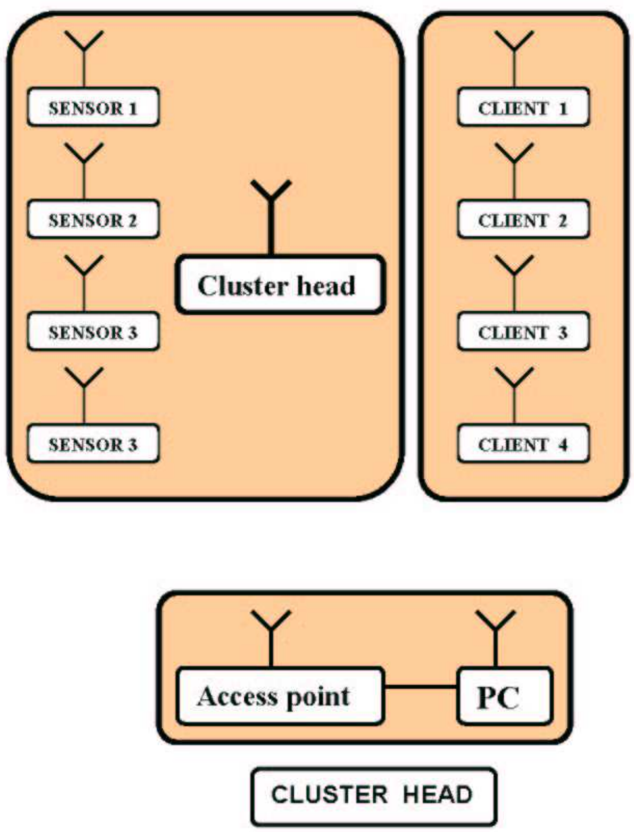

Figure 3

half/full duplex operation, auto negotiation. IEEE802.3/ 802.3U complaints. It is supporting I^2C which is interfaced to microcontrollers.

d. NM6000 module

NM6000 module is 802.11b WLAN module for WIZnet. Using WIZnet driver for WLAN connectivity it can communicate with access point in the client mode. It supports IEEE802.11b and 802.3 standards. Data rate is 11, 5.5, 2, 1Mbps. Center frequency is of the order of 2400 MHz.

2.1.2. Cluster Head Hardware

Cluster head consists of remote access point hardware wired to real time high end server. This module has the following features high computational and analysis capability, high powered wireless transmission capability to connect various external clients distributed at distance. It is complaints IEEE 802.11b 11Mbps.

3. Software implementation

The block diagram (Fig. 3) of the AE sensor networking is shown in the schematic diagram. The basic requirement in the software design is to configure different sensor nodes for the required gain in dB, threshold level and enable / disable various sensor nodes. The required settings are set by the various clients using different web pages for each node. The second requirement is to collect acquired AE data from each node and transmit the data to the cluster head. The cluster head analyses these data and generates graphical display information and AE parametric information to various clients. More detail on the design concept is discussed below.

a. Sensor head software

A real time operating system is running on all nodal hardware's. It consists of following tasks.

i) Configuration task
ii) Data acquisition task
iii) Data transmission task

i) Configuration task

When the power of nodal hardware is switched ON it runs configuration task and each node has unique IP address. All the sensor nodes are configured as server and are in the listening mode to get the configuration data from the cluster head. The data received by each sensor node selected is flashed back to the client terminals to check the calibration of the system. Once the calibration is over, configuration task goes to the suspended mode and the nodal sensor goes into data acquisition task and data transmission task simultaneously. Configuration interrupts from the WIZnet module will resume configuration task again if required.

ii) Data acquisition task

In the acquisition mode, the sensor node hardware module generates an interrupt at the falling edge of rise time signal and invokes interrupt service routine (Risetime-ISR). The Risetime-ISR starts a 32 bit counter used for source location purpose and also acquires analog RMS data. At the end of the AE event another interrupt is generated (Eventend-ISR). Eventend-ISR interrupt changes the state of the data acquisition task from wait state to ready state. Data acquisition task acquires peak value, external parameters and all the counter values which are in the CPLD and reads on the fly 32 bit source location counter value and stores in the external RAM as a data packet and goes to the wait state.

iii) Data transmission task

Data transmission task is listening for the connection of cluster head. When the connection is established the data from the external RAM through WIZnet module is transmitted to the cluster head and the data transmission task goes to the wait state.

b. Cluster head software

i) Data acquisition client task
ii) Data server task

The configuration data from the remote clients directly connects each sensor through cluster head using TCP/IP telnet protocol. In this case, no tasks are running on the cluster head. Cluster head is running with two task Data acquisition client task and Data server task. The source location software in the three configuration AE sensor mode to locate planner defect locations using intersection of hyperbola.

i) Data acquisition client task

Data acquisition client task connects individual sensor nodes sequentially and collects the data packets and stores in the cluster head in the form of file. This data is further analyzed in the cluster head and generates various information regarding the AE activity.

ii) Data server task

The acquired and analyzed AE data which is in the cluster head is connected to various remotely placed clients using TCP/IP protocol. The various clients receive display information in the form of web page refreshing with regular interrupt.

4. Conclusion

The paper described is recent work in acoustic emission sensor networking in field of Non destructive testing (NDT). In conventional sensor networking approach the environmental parameters viz. temperature, pressure, humidity, wind speed and direction, toxic gas concentration etc. in the vicinity of the sensor zone is acquired and processed. Whereas in AE sensor networking, the structural integrity of the component under test is detected dynamically by AE nodes even when the source of disturbance generated at a distance. The other difference is the conventional sensor networking for example toxic gas concentration varies with distance hence, different sensor nodes collect different concentration of toxic gas. Whereas in AE sensor networking the AE signal generated within the structure is detected by different nodes with only time lags. Hence, the processing of data in AE sensor networking is a dedicated development. With respect to source location in AE sensor networking each sensor node acquires the data from the source at different time and using computation we precisely detect the coordinates of the source which has been arrived but in conventional sensor networking approach the sensor node itself is the location of the source for acquiring the data. A very few developments has taken place so far in this field of sensor networking.

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