Development of Ship Data Acquisition Embedded System

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Abstract **– This research is part of the development of Data Acquisition embedded system that specifically use in ship. The purpose of this data acquisition system mainly is to acquire data from multiple sensors or others related external devices and it will further discuss in this paper. The data collecting, hardware design, software design and the final project outcome of this data acquisition system will be discussed in this paper**.

Index Terms**— Data Acquisition, Microcontroller, Ship, Sensors.**

I. INTRODUCTION

Ship or vessel is a transportation tools used such long time ago. From the development time to time, technologies use in a ship are getting more complex. Due to the requirement needed in the ship gradually increase the systems inside the vessel become more composite. Those important systems in a ship are depending on what type of ship it is. Basically, some of those systems are information system, monitoring system and the navigation system which is the main systems in a ship.

For different purpose, different type of equipments and systems will include in a ship. For instance, the military type of vessel will concentrate their system in attacking power, equipped with military devices and spying systems. On the other hand, some commercial type vessel such as cargo ship's system will more concentrated on the shipping capacity and some container management systems. However, some basic aspect such as navigation system is the foundation needs for a modern ship.

Some of the information from this system needs to be gather and performing the analysis work. Hence, vessel data acquisition is essential in a vessel to let the shipping crew or technical staff to complete their task.

Shipbuilding commissioning is an action that must perform after a ship finish construct. Before a ship is ready for commercial usage, a ship must pass through several milestones. Besides, all equipment needed to install and test, all problems have to be identified and corrected. Besides, respective shipping crew must be extensively train to make sure there will no problem when the ship is ready to use [1]. These steps are important due to ship navigating is a challenging task and will bring fatal issue if anything goes wrong. During the evaluating process, the data acquisition unit becomes an important equipment to gather all the related information.

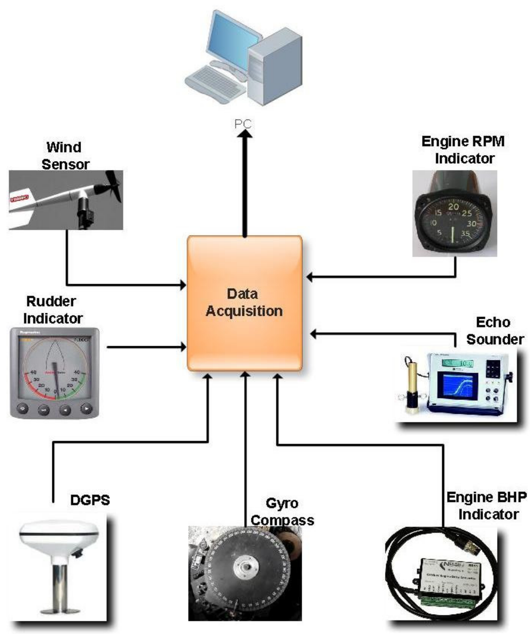

Fig.1. Data Acquisition embedded system concept diagram.

The data acquisition system in this research project is mainly collect data from sensors and output to the respective computer. Details of the design will be further discussed in following section and the figure below shows the system concept for this research project.

II. HARDWARE DESIGN

Main purpose of this data acquisition system is to obtain the relevant information from the sensors and its connected peripherals. The specs of this device are listed as below:

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- Able to obtain 7 channels of the NMEA-0183 serial data. The NMEA-0183 serial data will output from the sensors and will be collect by the data acquisition device.
- Included with 3 channels of ADC. Some sensors will output analog voltages to shows the certain information, thence ADC is required.
- Consist of 2 channels of pulses input. Some sensors will have pulses output to indicate the respective sensor's information.
- All gathered information will output to PC through USB port.

Following diagram shows the hardware design concept for this data acquisition system:

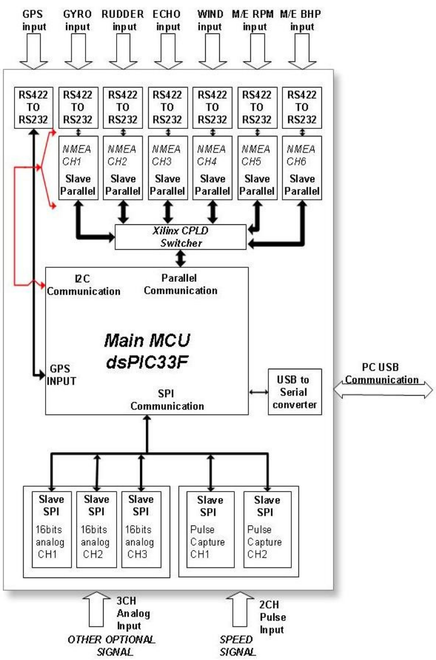

Fig. 2. Hardware design concept diagram.

The electronics system inside this device consists of 12 microcontrollers. Each microcontroller will assign with specific task and run parallel while performing their task. Basically, it divided into 4 main parts which are:

- Main microcontroller part, for handling major processes.
- Serial data modules, combining all serial data (NMEA-0183) inputs to main microcontroller.
- Analog input and pulse capturing modules
- USB to serial converter which responsible to output the data serially to PC through USB port.

This data acquisition system is using the 16 bits microcontroller, dsPIC33FJ256MC710 as the main processing unit. It is responsible to collect all data from slave microcontrollers, performing data processing and output the processed data to the PC through USB port. Besides, this device is configurable and the main microcontroller will receive the configuration signals and execute the necessary setting steps.

The 6 channels of serial data modules are using 8 bits microcontroller (PIC18F24J10) as its processing unit. These modules receive data from sensors in NMEA-0183 format. The data received will perform some basic checking and then will pass to the main microcontroller when the main microcontroller sends a request signal to them. The communication method in-between main microcontroller and serial data modules are parallel bus. A CPLD from Xilinx had used to switching the parallel bus channels. The reason to use parallel bus as the communication line is because the data passing time in between them need to be fast.

The I2C communication line in between main microcontroller and the serial data modules is used for sending the configuration commands.

The 7th channel of serial data is GPS signal. This signal will directly input into the main microcontroller. This signal need to direct input to the main microcontroller and direct process by the main microcontroller. This is because the GPS data is important in the time synchronization processes. All the 7 channels serial data that input into this system is in RS422 communication standard. Hence, all these data will go through a RS422 to RS232 converter since the microcontrollers support only RS232 standard.

All 7 channels of serial input consists of data from gyrocompass sensor, ship rudder indicator, echo sounder (depth sensor), wind sensor, main engine RPM indicator, main engine BHP indicator, and GPS/DGPS data.

The 3 channels of ADC modules consist of 3 16 bits A/D converter, with 250KSPS data sampling speed. These ADCs are connected with its own microcontroller. The ADC's microcontroller will capture the ADC data which is in 16 bits format and pack them into 8 bits data format and ready to send to main microcontroller. This is due to SPI bus had used to communicate with main microcontroller and it is in 8 bits communication format.

The reason these ADC not directly connect to main microcontroller is because some basic filtering able to perform in the ADC's microcontroller before the data send to the main processes. On the other hand, the work load on the main microcontroller will be reducing too.

The ADC input is required and ready for some sensors that might output analog voltages. There are some sensors that will output analog voltages. For example, main engine RPM indicator and main engine BHP indicator which will output analog voltages or serial output from some external modules to shows the engine status. So, the ADC input is act as optional sensor input for this data acquisition.

Next, the pulse capturing module in this system assigned to capture sensors data that may output pulse signal. One specific slave microcontroller is dedicated to capture each module. The difference between these 2 channels is the input type. One is for non-contact pulse signal and another is for contacted pulse signal. The contacted pulse signal will isolate using a photo-coupler. The sensors that might output pulse signal is vessel speed sensor. The pulse will indicate the vessel travelling distance and time, with this 2 information, the speed of vessel can be calculated. The speed signal may also output in NMEA-0183 format, thence, the pulse input is also optional input for the speed signal.

Main microcontroller will routinely capture all data from slave microcontrollers and output the data after process. The final processed data will be output through the USB port to the PC. The USB to Serial converter was included in the system by embedded the converter IC inside the electronics board of this data acquisition system.

III. SOFTWARE DEVELOPMENT

In this section, the firmware algorithm and the system process will be discussed. As mention before, the main task for this data acquisition is to collect all relevant data and output the specific PC for further data analysis system.

To simplify the concept, the program flow chart below shows the operation in the main microcontroller.

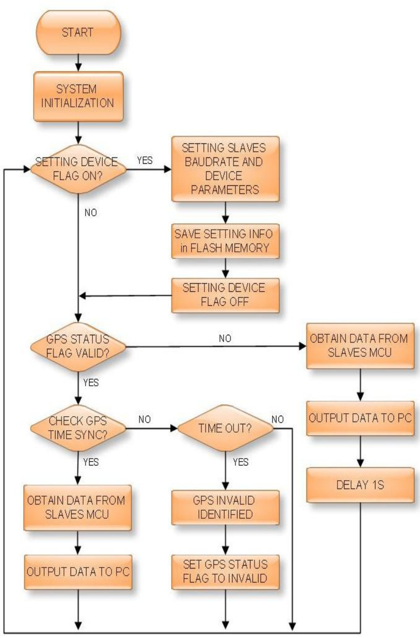

Fig. 3. The data acquisition main firmware routine.

The main controller firmware will start with the system initialization once it is power on. Besides the basic initialization for the main microcontroller, the system will also check for the previous user setting in the flash memory and recover the previous user configuration of the system in the system initialization process. After the one time initialization, the algorithm will enter into an infinite loop which will work until the device power off.

Inside the main loop, the main microcontroller will check the setting device flag status. If the flag is on, the setting action will be performing. Slave microcontroller will be set to desired setting, and some parameter in the process will be set too. Besides, all the relevant setting data will be save in the flash memory so that the setting can be resume back to the user desired configuration after the device turning on and off.

The dsPIC33F in this system has 2 hardware UART modules. UART2 had use to monitoring the user configuring sentence. Once the sentence received, the flag will turn on and the flag will keep on monitoring in the main loop. The setting flag will turn off after all the setting process done. The status will be check again in the coming loop. Figure below shows the UART2 interrupt service routine that used to monitoring the setting data configure by user.

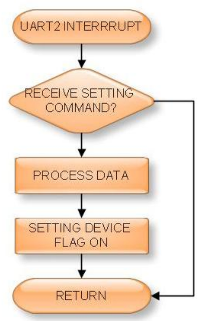

Fig. 4. UART2 Interrupt service routine.

After the setting flag checking, the main controller will check for the GPS status. As shown in figure1, the GPS data is directly connected to the main microcontroller. The GPS data will being monitored and the GPS time, GPS status and 2 GPS NMEA sentence will being captured. The GPS status that being check will use in this part. If the GPS is valid, all data being captured will output to PC with the synchronizing the output time interval with the GPS time. Else, the data output time interval will output using the internal timer. Following figure shows the UART1 interrupt service routine that serve for the GPS data.

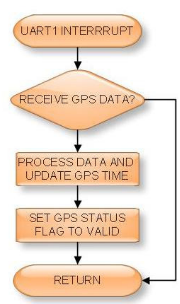

Fig. 5. UART1 Interrupt service routine.

A time out counter had been added in the routine to check if the GPS data not being update or sync for 10 seconds, the system will declare the GPS to down status. The status of the GPS will keep on invalid until the UART1 GPS data being update.

For the serial data modules, the process involve basically is handling the data input, packing data for output to main microcontroller and monitoring the configuration command from main microcontroller.

The ADC modules will mainly processing the ADCs reading, packing the data to transmit to main microcontroller and monitoring the configuration command. In addition, the moving average filtering method had implemented in the ADC modules. The numbers of data samples in the filtering process is configurable by user.

On the other hand, the pulse capturing modules will calculate the input pulse period by using the combination of external interrupt and timer interrupts. The pulse period information will also pack in to SPI 8 bits data format to send to main microcontroller.

IV. INPUT DEVICES

This system is able to input total of 8 different types of sensors data. These sensors are:

- *GPS/DGPS Receiver*, use to shows ship position and ship speed signal.
- *Gyro Compass*, for indicating the ship heading signals.
- *Rudder Angle Indicator*, use for acknowledge the ship's rudder angle for controlling the ship's navigation.
- *Doppler Speed Log*, to monitoring the ship speed and not to rely only with the DGPS on the ship speed.
- *Anemometer and Anemoscope*, to obtain the wind direction and wind speed signal.
- *Echo Sounder or Depth Sensor*, for observing the depth of the sea at the position of the ship.
- *Main Engine RPM signal*, for monitoring the RPM of the ship's engine.
- *Main Engine BHP signal*, for monitoring the horse power of the ship's engine.

The GPS data in NMEA-0183 format will monitor by the main microcontroller. The GPS time and the GPS status was use in the algorithm for the time synchronization. Besides, 2 sentences will capture and output to the PC and this 2 sentences are GPGGA and GPVTG. GPGGA stands for global position system fix data, it consist of some GPS basic information such as location and UTC time. The GPVTG stands for actual tracks made good and speed over ground. It provides the moving vehicle's speed by using the GPS technology.

Gyro compass use to determine the actual heading of the vessel in degree, and it also called as Heading Indicator. In essence, it is a compass that able to find the earth true north by using a fast spinning gyroscope wheel that being powered electrically [2]. The output from the gyrocompass is serial and in NMEA-0183 format with sentence heading of HEHDT. In this NMEA sentence, user will able to know the heading value in range of $0^{o} \sim 360^{o}$.

Information from Rudder Angle Indicator is also come serially and in NMEA-0183 format. The captured sentence is IIRSA which stands for Integrated Instrumentation for II and Rudder Sensor Angle for RSA. From the sentence, rudder starboard direction can be obtained.

Doppler Speed Log use in vessel will return the ship's speed signal. This kind of equipment usually will give two type of output which is serial output (NMEA-0183 format) and pulse output. The NMEA-0183 sentence for speed signal is VDVTG which means Doppler Track Made Good and Ground Speed. The main information will obtain from this sentence is ship speed in unit Knots and in unit Km/h. On the other hand, the pulse signal output format is in 200 or 400 pulse/Nm (pulse per nautical mile). The device will output pulses to indicate the ship's travel distance. By capturing the pulses and obtain its pulse period, the ship's speed can be known. The details of calculation will be discussed in the results.

Anemometer is the device to measure wind speed, while anemoscope is the device to measure wind direction. Wind information is important in vessel navigation. The wind information in vessel was called apparent wind. It is the wind direction and wind speed which can be feeling while the ship is moving and it is the forward of the true wind [3]. The equipment nowadays usually combines both together and produces a single combined output. By outputting the NMEA-0183 (IIMWV or WIMWV) sentence from these devices, user can know the wind speed and the wind direction.

Echo sounder is a device to detect or measure the depth of sea which based on the principle of reflection of the echo wave that transmitted by the wave generator [4].

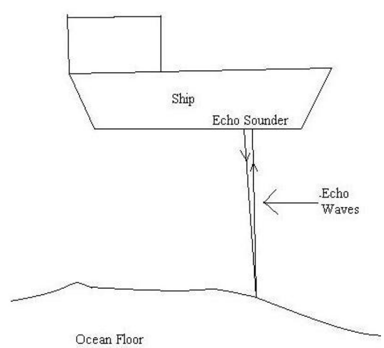

Fig. 6. Echo sounder working principle [4].

This device returns NMEA-0183 signal and using the sentence SSDBT which will give the sea depth in units of Feet, Meter and Fathom.

The last 2 input devices are Main Engine RPM and Main Engine BHP. There are some equipments uses to converts the information of ship engine into readable format and able to let us know the ship engine speed. This device will output the NMEA-0183 sentence (ERRPM) which will include the engine RPM (Revolution per minute) value. Main Engine BHP indicator indicates the ship main engine brake horsepower to let the vessel crew to monitor the status and health of the ship's engine. From the equipment, the serial output in NMEA-0183 format is available. The sentence used is ERBHP, which will include the information of the valid torque value of the main engine.

V. RESULTS AND DISCUSSION

For the pulse capturing part, the input pulse speed can handle pulse in range from 0.0033Hz till 20 KHz. Due to the system requirement to handle the Doppler speed log output is only up to 100 Hz of frequency. Hence, a high-pass filter had been applied to the pulse capturing part. The input frequency that higher than 100 Hz will consider as input noise signal. For the pulse calculation, the formula using the pulse period for each pulse input to obtain the ship speed in Knot and km/hr units. The formula is $\frac{1Nm}{PT*Tp} * 3600sec$, PT stands for Pulse Type and Tp is the captured Pulse Time. There are 2 type of Pulse Type; it is either 200 or 400. For example if the pulse time is 2 second and for pulse type 200, the ship's speed in knots unit will be 9knots. Converting to Km/h we can multiply knots with a 1.852 constant. Hence, the system able to detect the ship's speed in range of 0.06 Knots to 900 Knots or in km/hr unit is 0.1111 Km/hr to 1666.8 Km/h. This range is sufficient enough for the speed of ship. In addition, the users are able to select the type of input pulse they desired. The GUI software can let them choose the either 200 or 400 pulse input type that user want to use.

On the other hand, the 3 ADC channels available are fully configurable by user. The user can configure its scale value, offset value and the filtering count. The filtering technique currently implementing is moving averaging filtering technique and the results of the ADC after added the filtering reach the accuracy of 2 mili-Volts in 10Volts range.

Regarding the 7 channels serial input modules, the configurable settings are their baud rates and the input types. The baud-rates selections for their RS422 input are 2400, 4800, 9600, 14400, 19200, 38400, 57600 and 115200. Besides, the input type for some input device can be selectable too. Such input devices are Rudder Angle Indicator, Doppler Speed Log and Main Engine RPM. Rudder Angle Indicator may have serial type output or Analog output. Doppler Speed log may have serial output, analog output or pulse output. Lastly, main engine RPM indicator may have serial output or Analog output.

Following figure shows the GUI software to let user to configure the Data Acquisition System and also to monitoring the Output Data from the system.

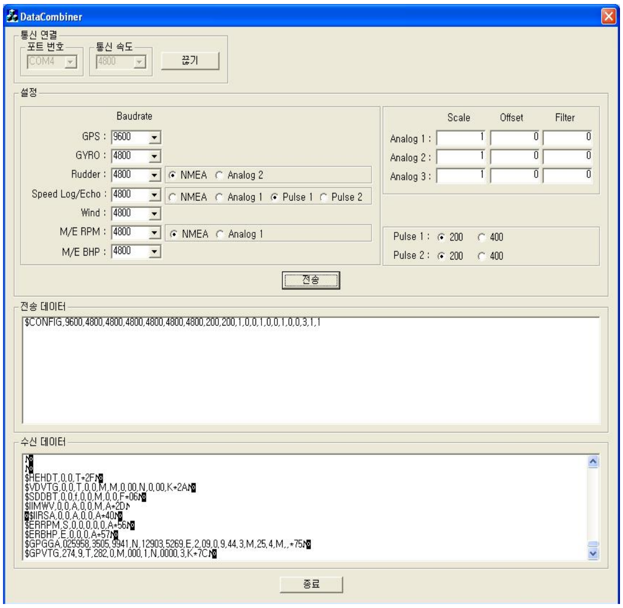

Fig. 7. GUI software for the Data Acquisition System.

The final output for this data acquisition is in the NMEA-0183 format with the combination of all input devices information. The sample outputs are as shown in below:

```
$GPGGA,091419,3506.0161,N,12903.5330,E,1,04,2.9
,21.5,M,25.4,M,,*76
$GPVTG,040.8,T,047.9,M,000.1,N,0000.1,K*78
$HEHDT,1.1,T*2F
$VDVTG,,T,,M,,N,,K*4B
$SDDBT,,f,0.2,M,,F*0C
$IIMWV,0.0,R,0.8,M,A*36
$IIRSA,0.0,A,0.0,A*40
$ERRPM,S,1,0.0,66.6,A*61
$ERBHP,E,1,0.0,A*56
```

Photos below show the final outlook for the data acquisition system. It was designed to be small size, compact, light weight and high mobility. The output data is output through USB and able to connect to any PC that has USB port.

The front view of the system consists of the main on off switch and the USB output port. The back view of the system consists of the connectors for the input devices and also the power input jack.

Fig. 8. Front View of the Data Acquisition System.

Fig. 9. Back View of the Data Acquisition System.

VI. CONCLUSION

This data acquisition is designed specifically for ship use and with specific input devices. The advantage for this design is easing the user in their ship monitoring or analysis work. Besides, it also simple to use and no need complex configuration steps. For the disadvantage, it is specifically design for specific type of inputs and lost the flexibility for user when the change of sensor is needed. For future work, the flexible design will be included to adapt more changes and adapt in wider applications.

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