

Chapter 6

Conclusions and recommendations

Chapter 6 conclusions are drawn about the developed in-house communication protocol for the ADES. Lastly future work and recommendations are presented. This includes possible improvement of the internal communication sub-system designed for the ADES as well as the implementation of the specified communication sub-system for the external interfaces.

6.1 Conclusions

6.1.1 The communication sub-system design for the ADES

This dissertation presented the design of a communication sub-system for AMB applications; specifically for the ADES. This particular communication system had to fulfil the exact needs of an AMB system. The total communication architecture was divided into two sections, the internal and the external communication system and by using the design process stipulated in Chapter 3 the optimum solutions were obtained. The external interfaces were determined and the optimum solution for each of the external interfaces were specified. The decision was made to implement only *standardized protocols*, to ensure *total compatibility* with commercial off the shelf components, for example laptops and SCADA systems. The external interfaces identified were the maintenance port, the SCADA and the remote access port. For the SCADA system the Profibus DP protocol was specified. For the maintenance port and the remote access port the Fast Ethernet protocol was specified.

The main requirements of the internal communication system to be implemented in AMB systems are robustness, reliability, cost effectiveness, expandability and shorter system integration times. The decision was made to develop an in-house protocol for the internal communication system.

The internal communication system would be responsible for the communication between the functional units that were directly responsible for the control of the bearing module. The main motivation was that the protocol can be developed for the *specific needs* of an AMB application.

One of the first goals was to determine exactly what data had to be communicated between which functional units, during which part of the control cycle. The other goals were to determine the timing constraints, synchronization constraints and what would most likely cause data corruption during communication.

It was decided to implement the RS 485 data transmission standard as the physical layer between all the internal functional units. The main motivation being that this is a robust data transmission standard that is highly noise immune due to their implementation of differential signalling. It was also decided to implement point to point connections to avoid a single point of failure which would be detrimental in an AMB system.

The decision was made to implement the communication controllers on FPGAs due to their concurrent capabilities. By selecting FPGAs it was possible to instantiate more than one communication controller on a single FPGA. The data link layer was also designed to transmit 16 bit values at a time. This was a very important requirement, keeping in mind that the AMB system works with floating point values. Two different error detection methods were implemented to aid in making the ADES more reliable. These two error detection methods are even parity and a 15 bit CRC which is the optimum solution for the amount of data transmitted over the communication channel. The data link also flagged errors that could compromise the safety of the AMB system. The data link layer also had the ability to replace the synchronization signal in the exceptional case that the synchronization signal malfunctioned. By implementing these functions local intelligence was added to the communication controllers.

6.1.2 Analysis of the designed ADES digiComm protocol

Two of the most important aspects of the ADES digiComm protocol are the timing and the synchronization requirements. It is crucial for each of the internal communication cycles to not exceed the 20 kHz (50 μ s) requirement. When analysing the timing for each of the communication cycles, the following is observed. During prompting the ISensorboard continued to communicate all the necessary values in 25 μ s. The power amplifier communication cycle takes 27 μ s when all the necessary data is transmitted as well as an extra data frame to illustrate expandability. Thus both of the communication cycles execute in half the time specified.

Synchronization is also one of the most important requirements of the ADES digiComm protocol, because one of the major issues of AMB systems is the noise caused by switching. The system was synchronized by routing the synchronization signal out on one of the CMOS digital channels. When monitoring the response of the various communication controllers to the sync signal, it is seen that once the rising edge of the sync signal is detected the communication controller

immediately starts to transmit or receive, thereby aiding in avoiding data corruption due to switching of A/Ds.

The physical layer of the ADES digiComm protocol was analysed by drawing eye diagrams and determining statistical properties of the eye diagrams. A low jitter signal was observed, thus the conclusion can be made that timing jitter will not result in bit errors. The maximum bit rate used for the ADES digiComm protocol is 8.3 Mbps when additional expandability is incorporated. The longest cable length paired up with this bit rate is 2 m. Furthermore these tests were conducted while the system was operational, and an immense amount of noise was present in the system.

When analysing the eye opening the SNR can be obtained. The SNR can be related directly to the bit error ratio (BER) in digital networks. A signal to noise ratio of 26.26 dB was obtained while the ADES was *fully operational*. This SNR barely had a discernable effect on the communication channel. Therefore it can be stated that the selected cable was an excellent choice and shielded the communication channel sufficiently from the immense amount of noise emitted by the ADES.

The last observed effect that can cause bit errors is the ringing effect caused by impedance mismatching. However the possibility that this will cause a bit error can almost be neglected, because even if the sampling point shifts to where the ringing occurs, the amplitude separation is still sufficient to register as a logic '1' or a logic '0'.

Not only was the physical layer extensively tested, but also the data link layer. After all the tests were conducted the following conclusion was made; all the implemented components were highly functional when subjected to normal conditions and when error conditions were induced the data link layer responded correctly.

When validating the total internal communication sub-system it was observed that each of the communication controllers operated precisely as required. Furthermore due to the development of the internal communication sub-system the system integration was simplified due to the utilization of communication controller that had the same functional architectures and by clearly specifying the memory address where the data had to be written into the DPRs.

6.2 Recommendations for future work

6.2.1 Motor drive

For the first version of the ADES the motor drive was a commercial off the shelf module due to design time limitations. For the next version the motor drive will be developed by a Master's student in the McTronX research group. It is advised to develop the motor drive to consist of the necessary components to enable digital communication between the motor drive and the main controller by implementing the ADES digiComm protocol.

6.2.2 Implementation of external communication architecture

It was not part of this project's scope to implement the external communication system. This project only entailed the specification of the external communication system and procuring the fitting hardware to establish communication to the external interfaces. Future work will involve implementing the external communication system.

6.2.2.1 Profibus DP

At this stage a commercial off the shelf Profibus DP card was procured to establish communication between the main controller and the specified SCADA. It is however advised to also implement the Profibus DP protocol on the Virtex 5 FPGA situated on the main controller. The reason being that the McTronX research group's main goal is to develop a competitive AMB controller that is very cost effective. By implementing the Profibus DP protocol on the main controller, the necessary hardware to procure is minimized. Furthermore the Profibus DP protocol also makes use of the RS 485 standards as the physical layer. Therefore the Profibus DP communication channels can also be routed out by the AXM-D03 card with no additional cost.

6.2.2.2 Fast Ethernet

During this project the following was done towards enabling communication via the maintenance port and via the remote access port:

- The necessary hardware was procured.
- The data that needs to be communicated via the maintenance port and the remote access port was specified.
- The data on the main controller was routed to the SBC by reading the DPR values into the DDR and transmitting the values via the PCI bus.

The next step will be to successfully interface a laptop with the SBC via the maintenance port and to interface a remote access server with the SBC via the remote access port.

6.2.3 Standardizing the ADES digiComm protocol

The option may also be investigated to standardize the ADES digiComm protocol according to nuclear standards. This can be done by obtaining the nuclear regulatory guides concerning data communication systems and conducting each of the necessary tests to ensure that the data communication system is sufficiently reliable and safe.

6.3 Possible improvements to the internal communication system

6.3.1 BERT (Bit error rate tester)

It is recommended to verify the physical layer by using a BERT (bit error ratio tester). This however was not possible; because it is a very expensive measuring instrument that exceeded the project budget.

6.3.2 Waveforms

The waveforms can be improved by decreasing the bit rate. Such a high bit rate is not required. It was only implemented to show the level of expandability of the system as well as that the ADES digiComm protocol still functions correctly at an increased bit rate.

6.3.3 Implementation of isolated drivers

To make the communication system even more robust and reliable isolated RS 485 drivers can be implemented.

6.3.4 Design of impedance matching circuit

Future work will also involve determining the frequency dependant characteristic impedance of the BLDN-9841 cable and the SCSI cable. Furthermore the impedance mismatch can also be eliminated by developing an impedance matching circuit between these two cables.

6.3.5 Error correction

At this stage the ADES digiComm protocol is designed to only detect errors and flag error conditions to indicate that the data received was corrupted. A next step would be to develop or implement a straightforward method of error correction.

6.4 Closure

The aim of this project was to develop a communication sub-system for the ADES. The ADES forms part of an AMB system for a helium blower. The communication sub-system had to identify all the needed internal and external interfaces as well as all the data that needed to be communicated. The external communication system would enable helpful monitoring of the system and the internal communication system will ensure effective control of the AMB system.

The optimum total communication architecture had to be determined and the relevant hardware had to be procured. An effective in-house protocol had to be developed and implemented between the internal functional units of the ADES. From the results it can be seen that a highly effective in-house protocol was developed and implemented which obtained all the stipulated requirements. The rotor of the AMB suspended helium blower was successfully operated at 19 000 r/min for extended periods without any failure. This was the first AMB system of the McTronX research group that implemented digital communication and the improvements due to this change were remarkable and will be used in all the future developments.