Project Title: Wireless DAQ using LabVIEW
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Acknowledgement

We would like to extend our gratitude to our faculty advisor Dr. Eroglu for his continuing support and dedicated guidance in the development and formulation of this project. We would also like to thank Bob from the IPFW technology department for helping us get the parts soldered on and Prof. Dewitt for his feedback and recommendations throughout the semester. Without their contribution, this project would have never been fully realized. And finally, a thank the entire Department of Engineering faculty at IPFW for giving us the opportunity to earn and apply the prerequisite knowledge and education that was put to work during this project.
Abstract

This paper is written as a continuation of the spring 2010 semester of work on the wireless data acquisition system using LabVIEW software. The project is the result of work done by senior design students in the Indiana University-Purdue University School of Engineering, Technology and Computer Science. This document is a written record of the process of building a final prototype based on the problems statement and chosen conceptual design on the previous semester. The proposal of the previous semester was to build a wireless data acquisition system and then process the conditioned signal through labVIEW software.

This report reviews the selected conceptual design of the previous semester, a brief description of the building process and any changes made to the conceptual design, testing results, the groups evaluations and recommendations, and a final conclusion to this project. Information will be provided for all of our processes, our reasoning, and final conclusions. All schematics, research, and calculations are provided for reference and understanding.
Section I: Conceptual Design
**Concepts:**

After researching these options, it was decided to narrow down our design possibilities by looking at which designs might and might not be possible to implement. We ended up with three remaining design concepts which included a switch circuit using the YS-C30H transceiver pair, Encoded signal circuit using a microcontroller and YS-C30H transceiver pair and a multichannel transceiver/receiver pair made by RF Solutions.

**Concept 1: Switch Circuit using the YS-C30H transceiver pair**

**Description:**

The fist concept is based around the idea of using a switch to select which measurement signal will be sent through the conditioning circuit to the transmitter. This circuit creates minimal interaction between the different measurement circuits and allows for a segmented circuit design. In this design we have a separate circuit for each of our measurement devices. The output of the measurement circuits will be fed into a switch which will be used to select the user's preferred signal. The preferred signal will then be sent to an A/D converter where it will be converted into a digital signal and then be sent to a universal asynchronous receiver/transmitter (UART) to prepare the data to be converted into a RS-232 signal by being sent into an RS-232 line driver. At this point the signal will be sent into the YS-C30H transceiver and be transmitted wirelessly to the YS-C30H being used as a receiver. During the wireless transmission the signal will be sent at one of the three frequencies supported by the YS-C30H which are 433 MHz, 868 MHz and 945 MHz. From the receiver the transmitted signal will be sent to RS-232 R/D line driver and then be sent through another UART to convert the signal back into the digital signal that was outputted from the A/D converter. The signal will then be sent through a D/A converter and then be fed into the SC-2345 DAQ and be sent to a computer terminal using LabView.

Each stage of this system can be described by a different section of hardware. The discrete hardware stages are displayed in Figure 1.

In this concept a YS-C30H transceiver pair is used to wirelessly transmit the signal in the design. This transceiver pair was chosen because it meets the distance requirements set for the project, leaves money in the budget for the conditioning circuits and the transceivers are made to work in combination with each other. The first concept also uses discrete parts to construct our conditioning circuits. Due to the use of the YS-C30H we are also using the RS-232 signal protocol. The main feature of this circuit is it removes the need to encode the different measurement circuits into on signal by using a switch that a user can use to select the measurement device which they wish to use.
Measurement Devices and Corresponding Circuits

Pre-Transmission Signal Conditioning Circuit

- Measurement Device Selection Switch
- Signal Conditioning / Control Signals
- A/D Converter
- UART
- RS-485 D/R Line Driver
- YS-C30H Wireless Transceiver
- ACK Signal

Post-Receiver Signal Conditioning Circuit

- RS-485 R/D Line Driver
- UART
- D/A Converter
- Signal Conditioning / Control Signals
- LabVIEW User Interface on Computer
- SC-2345 DAQ

Figure 1: Concept 1 Block Diagram
Concept 2: Circuit using the RF Solutions

Description:

This concept is created around the idea of sending multiple data signal simultaneously. A block diagram of this design is shown in Figure 2. Each of the measuring instruments will use a unique circuit to develop a signal in the range that is usable by the analog to digital converter where it will be converted into a digital signal and then sent to RF solution wireless transmitter.

The RF solution transceiver is used to transmit the data up to 10km. This is a high end transmitter and receiver pair which is very expensive. The cost of this instrument exceeds our budget.

The signal received is then fed into a post receiver signal conditioning circuit. SC 2345 DAQ receives the signal and then sent to LabVIEW user interface on computer.

Figure 2: Concept 2 Block Diagram
Concept 3: Multiplexing Circuit using the YS-C30H transmitter and YS-20UA receiver

Description:

This concept is created around the idea of sending multiple data signals across one RF channel. A block diagram of this design is shown in Figure 3. Each of the measuring instruments will use a unique circuit to develop a signal in the range that is usable by the Analog to Digital Converter (ADC). The measuring circuits are connected either directly to a multi-channel ADC, or to a single-channel ADC via a multiplexer.

A microcontroller will be used to select which signal to convert and to command the DAC to begin the conversion process. The microcontroller will either cycle through each input channel, or for a small additional cost, will cycle through only the input channels selected by means of DIP switches. Once the conversion is complete the digitized value is transferred to the microcontrollers’ memory. The address of the multiplexer used to select the signal is appended to the signals’ value. This combined data packet is then loaded into a UART, converting the data packet into a bit stream. The next stage is an RS232 line driver which converts the TTL bit stream into higher voltage RS232 bit stream in order to communicate with the YS-30H transmitter.

The YS-30H transceiver is used to transmit the signal up to 10 Km, if both the transmitter and receiver are in the open with direct line of sight. The range of the signal is reduced by the amount of obstructions between the transmitter and receiver.

Since it is not necessary to have two-way communication between the transmitter and receiver pair, a lower power YS-20UA transceiver is used to capture the bit stream. The bit stream is loaded into the memory of the second microcontroller via a UART connected to an RS232 line receiver. This microcontroller then removes the appended address from the digitized signal. The address is used by the microcontroller to select which output channel of the multiplexer to use. An Analog to Digital Converter (ADC) is used to change the digital signal back into analog.

Each output channel of the multiplexer is connected to a different input channel of the SC-2345 DAQ and from there into the LabView software. A program written for LabView will identify each channel as a different measured parameter, and using mathematical models of the measuring devices, convert the signals into the actual value of the measured parameter.
Figure 3: Concept 3 Block Diagram

Concept 4: YS-C30H Pair Using Multiplexer
Measurement Devices and Corresponding Circuits

Pre-Transmission Signal Conditioning Circuit
- Measurement Device Selection Switch
- Signal Conditioning
- A/D Converter
- MCU Memory
- MCU Control
- RS-485 D/R Line Driver
- UART
- YS-C30H Wireless Transceiver

Post-Receiver Signal Conditioning Circuit
- MCU Memory
- D/A Converter
- MCU Control
- Multiplexer
- RS-485 R/D Line Driver
- UART

LabVIEW User Interface on Computer
SC-2345 DAQ

Figure 4: Concept 4 Block Diagram
**Input measuring circuits**

There are three different types of measurements being made; displacement (strain), temperature, and acceleration. Each of these types of measurements requires a different circuit to convert the measured parameter into an electrical signal at a level safe to apply to the ADC. These circuits will use a common power supply of 15 VDC.

- **Strain:** A Wheatstone bridge will be used to measure the minute change in resistance of the strain gauge. This circuit is represented in Figure 5.

![Figure 5: Strain Measuring Circuit](image-url)
• **Temperature:** The user will have a choice of using an RTD or a thermistor to measure temperature. Each of these devices will use a voltage divider in order to develop the input signal for the ADC as shown in Figure 6. However since these devices do not have the same resistance values, the voltage dividers are necessarily different. A double pole double throw switch is used to select which signal is sent to the multiplexer and also to tell the encoding device which signal is present so the correct mathematical model can be used when decoding the signal.

![Figure 6: Temperature Measuring Circuit](image-url)
Final Concept Design:
The final concept is created around the idea of sending multiple data signals across one RF channel. A block diagram of this design is shown in Figure 4. Each of the measuring devices will use a unique circuit to develop a signal in the range that is usable by the Analog to Digital Converter (ADC). The measuring circuits are connected either directly to a multi-channel ADC, or to a single-channel ADC via a multiplexer.

A microcontroller will be used to select which signal to convert and to command the DAC to begin the conversion process. The MCU will be used to poll and send measurement signals that are chosen through a LabVIEW program. The selected signal is then sent through an internal UART of a MCU and then sent in to a RS-485 Line Driver so that it is able to be transmitted through the YS-30H. The YS-30H transceiver is used to transmit the signal up to 10 Km, if both the transmitter and receiver are in the open, with direct line of sight. The range of the signal is reduced by the amount of obstructions between the transmitter and receiver.

A MCU on the Reception side of the circuit is used in conjunction with a digital to analog converter to convert the signals in to a analog voltage signal that is sent into the SC-2345 DAQ and the LabVIEW program. The MCU also creates an acknowledgement/select signal that is sent through the MCU UART and a RS-485 Line Driver and is sent back through the reception YS-C30H transceiver back to the transmission circuit.

The LabVIEW program then uses a voltage to measurement and signal transmitted to create a signal to determine which measurement device the signal comes from. The LabVIEW program then uses specific conversion for the specific measurement device. The LabVIEW program then also displays the converted values to the user. The LabVIEW program also allows the user to create a signal that allows the user to select which measurement devices will be polled.
Figure 7: Overall Final Design Flowchart
Transmission MCU

The transmission circuit is controlled by a C8051F340 MCU. There are two input signals that are sent into the MCU. There is a measurement signal and an acknowledgement and select signal. The digital measurement signal comes from one of the five measurement devices that had been polled by the MCU and the analog to digital converter. The acknowledgement and select signal comes from a transmission from the receiving transceiver. A flow chart that is illustrating the transmission portion is given in Fig. 8.
Receiver MCU

The receiver circuit is controlled by a C8051F340 MCU. There are two input signals that are sent to the receiver MCU. There is a measurement signal from the transmitter and a select signal. The measurement signal from the transmitter is composed of a measurement signal from one of the measurement devices and identification signal from measurement device. The select signal is a user defined signal that is defined in the LabVIEW program. A flow chart for the transmission MCU can be seen in Figure 9.
LabVIEW Flowchart

The LabVIEW program receives two input signals; measurement signal and identification signal. The measurement signal comes into the SC-2345 DAQ using one of the input channels. The program then determines the measurement device that the signal is coming from. The signal is then sent to a corresponding Voltage to measurement unit conversion program. These conversions are based on the calculations and equations in Appendix A. After the unit conversion, the converted measurements are displayed to the user. A flow chart for the transmission MCU can be seen in Figure 10.

Figure 10: LabVIEW Flowchart
**Input interface circuit:**

**Purpose:**

The primary purpose of the input interfacing circuit is to sample the desired signals, convert them to a digital format, and forward the digitized signal to the transmitter. A secondary function is to provide a visual acknowledgement of which signals have been received at the output circuit.

**Overview:**

The input circuit microcontroller receives a signal from the microcontroller at the output interfacing circuit. This signal is composed of two parts. The first part of the signal is used to determine which channels are to be sampled. The last part is used to generate the visual acknowledgement.

The microcontroller will rotate sampling each of the desired channels. The first step that the microcontroller performs is to command the DAC to generate a reference signal. The sensitivity of the ADC is adjusted by varying its reference. The second step the microcontroller performs is to inform the ADC which channel to sample. The microcontroller then gives the ADC the command to begin conversion. While the conversion is in progress, the microcontroller will determine which signal has been received by the output interface circuit. Then it informs the LED driver which acknowledge LED to energize. The next step in the process is to accept the digitized signal from the ADC. The microcontroller then appends addition to this signal. The signal is then sent to a RS485 driver/receiver via an internal UART. The RS485 D/R sends the data to the output interface via a wireless transceiver.

**Components:**

**Silicon Labs C8051F340 microcontroller:**

The microcontroller is used to control the order in which all of the operations are performed. The core of the microcontroller uses pipeline architecture and executes 70% of all instructions in one or two system clocks. The controller can perform 48million instructions per second, and has 4352 bytes of RAM. The controller has 40 I/O ports and supports SPI, SMBus, and UART serial ports.

**EXAR RS-485 Receiver/Driver:**

The RS485 R/D is used to interface between the microcontroller and the wireless transceiver. This device has a maximum data rate of 20 Mbps in full duplex mode.

**NXP Semiconductors PCA9551 LED driver:**

The LED driver communicates using I²C bus communication. This is compatible with the SMBus format that the microcontroller uses. The driver contains 8 open-drain outputs which can directly drive LED’s to 25mA.
Linear Technology LTC2308 Analog to Digital Converter:

The ADC is used to sample an analog signal and convert the sample to a digital value. This 12 bit ADC has a maximum sample rate of 250ksps. The ADC also contains an 8-channel internal multiplexer which can be used as 8 single-ended inputs, 4 differential inputs, or any combination of the two types. In addition the signal may be either unipolar or bipolar. The ADC communicates with the microcontroller via Serial Peripheral Interface (SPI). The ADC may use either its internal reference of 4.096V or an external reference.

Linear Technology LTC1257 Digital to Analog Converter:

In this circuit the DAC is used to generate the desired reference signal for the ADC. This device also communicates with the microcontroller via SPI. A 12 bit DAC is somewhat of an overkill for this application, but the component was chosen since it is already used in the output interface circuit.

![Figure 11: Input interface Circuit](image-url)
Output interface circuit:

Purpose:

The function of the output interface circuit is to convert the digital signal received from the input interface into an analog output which is directed into a DAQ signal conditioning module. This circuit also informs the input interface which channels need to be sampled and the last signal it received.

Overview:

The microcontroller receives an input from the DAQ. These bits represent which input channels need to be sampled. The microcontroller appends addition to the acknowledgement of the last sample received and sends it to the wireless transceiver via an internal UART and an RS485 D/R. Upon reception of the signal from the input interface, the microcontroller will separate the specified address from the data signal. The data signal is sent to the DAC which recreates the sampled input and sends it to the DAQ signal conditioning module. The added address is sent directly to the DAQ so that the Labview Software will know which signal it has received.

Components:

Silicon Labs C8051F340 microcontroller:

The microcontroller is used to control the order in which all of the operations are performed. The core of the microcontroller uses pipeline architecture and executes 70% of all instructions in one or two system clocks. The controller can perform 48 million instructions per second, and has 4352 bytes of RAM. The controller has 40 I/O ports and supports SPI, SMBus, and UART serial ports.

EXAR RS-485 Receiver/Driver:

The RS485 R/D is used to interface between the microcontroller and the wireless transceiver. This device has a maximum data rate of 20 Mbps in full duplex mode.

Linear Technology LTC1257 Digital to Analog Converter:

In this circuit the 12-bit DAC is used to recreate the sampled input signal. This device communicates with the microcontroller via SPI.
Figure 12: Output interface Circuit
Changes from Original Design:
Selected radio

- YS-C30H to ConnexLink 4790

  • The radio change was necessary since the YS-C30H does not fall into the ISM frequency band in the United States.

  • This also required a change in communication between the MCUs and radios from RS-485 to RS-232.

  • The chart below shows how to select an operating frequency in the United States.

  ![Flowchart showing how to select an operating frequency](chart.png)

  • Specification of ConnexLink 4790

    Max RS-232 transmission rate: 115.2Kbps

    Wireless transmission rate: 76.8 Kbps

    900 MHz Frequency Hopping Spread Spectrum modulation

    Range: up to 20 miles line-of-sight

    Range indoors: 1500 m
ADC

- LTC2308 to MAX186
  
  • Original ADC: LTC2308
    
    – QFN-24 package with center ground pad.
    
    – Max sample rate: 500 kHz
  
  • New ADC: MAX186
    
    – 20 pin DIP
    
    – Max sample rate: 133 kHz
    
    – 12 bit SAR.
    
    – Both single and differential channel inputs.
    
    – Internal 4.096V reference

5 volt regulation circuit

- Zener Diode network to LM7805
  
  • Zener Diode network
    
    – Max VDD for ADC limited to 5.25V
    
    – Simulation provided a max voltage of 5.1V
    
    – Implementation resulted in over 5.3V
  
  • LM7805
    
    – Voltage stable at 4.95 V in both simulation and implementation.
Building Process:
ADC/DAC Simulation:

Calculation:

12 bit ADC encodes the analog input in 4096 levels

\[ 2^{12} = 4096 \]

\[ D_{out} = \frac{V_{in} \cdot V_{ref}}{2^n} \]

Dout = decimal value of the binary output

Vin= analog input

Vref= reference voltage of the ADC = 5V

N= bits=12
Transmitter Multisim Layout
Transmitter Interface Circuit:
PCB Layout in Ultiboard

Input Board View
Output Circuit Board
Receiver Interface Circuit:

Output Board View

Top

Bottom
MCU software development using silicon laboratories C8051 F340-TB

Following is the combined code flow chart:

Transmitter MCU flowchart:
Receiver Flow Chart:

### Receiver Code

<table>
<thead>
<tr>
<th>RS-232</th>
<th>Reception Function</th>
<th>Internal Processing</th>
<th>DAC Code</th>
<th>DAC Input/Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UART Communication:</td>
<td></td>
<td>Timer 2</td>
<td>Chip Select 3.4</td>
</tr>
<tr>
<td></td>
<td>(stage = 1)</td>
<td></td>
<td></td>
<td>Clock 3.5</td>
</tr>
<tr>
<td></td>
<td>Receive Low Byte</td>
<td></td>
<td></td>
<td>Signal 3.6</td>
</tr>
<tr>
<td></td>
<td>(stage = 2)</td>
<td></td>
<td></td>
<td>Latch 3.7</td>
</tr>
<tr>
<td></td>
<td>Send Low</td>
<td>Error Check = TransmitByte_n For n = (c, d, e, f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acknowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(stage = 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Receive High Byte</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(stage = 4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Send High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acknowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(stage = 5)</td>
<td>DataSig(n) = TransmitByte_n</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reset</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LabVIEW

LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. It offers unrivaled integration with thousands of hardware devices and provides hundreds of built-in libraries for advanced analysis and data visualization – all for creating virtual instrumentation. The LabVIEW platform is scalable across multiple targets and OSs, and, since its introduction in 1986, it has become an industry leader.

The issues faced when using LabVIEW are the following:

- Compatibility Issues
- Legacy vs. DAQmx
- NI website is not updated

Solutions used to solve the problems faced in the project are the following:

- Able to find solutions after lot of research.
- Help from the Indiana LabVIEW Users’ Group (Prof. Edward Dewitt - Technology department)
Analog to Digital Converter communication

Digital to Analog Converter communication
LabVIEW Files

Screen shots of the labview files for the following measurements:

RTD

Block Diagram:

Strain
Voltage:

Block Diagram:
Recommendations

A recommendation to any future Senior Design group is to verify that they have access to the equipment necessary to implement their design. In our case, we had chosen an ADC with a QFN-24 footprint with an additional ground pad in the center of the bottom. The leads on this package are all recessed under the chip. After a couple of attempts the Technology Department was able to cut a board for us. However, because of the chip’s architecture, they were unable to solder good connections to all of the pins. We were forced to select a new ADC with a different footprint, resulting in at least a week and a half delay of implementing the design.

If reworking this project, we recommend adding external memory to the MCU’s. Several times during the software development we were forced to recode the software due to running out of available memory. Also, better error detection and correction algorithms could be implemented. In addition to this the radios could be placed in the API mode, which would allow several bytes of data to be bundled into one packet. Currently the radios are in a transparent mode, each byte is transmitted as it is received.

Another recommendation would be to find a different software development platform. The platform included with the C0851F340 development board left a lot to be desired. It is essentially an evaluation product. We noticed that as the project code became longer, the less specific the error codes became. The compiler also did not have any predefined functions like in Embedded RTOS, which would have helped simplify the coding.

Finally, we realize that you have to work with the equipment specified by your customer. However, eventually one must bite the bullet and upgrade obsolete equipment. The software for the DAQpad equipment the school has was last supported by Windows XP. National Laboratories has new software for current operating systems, but this software does not function with the Legacy DAQpad equipment. We recommend checking the technical support available for any legacy equipment you must work with. If none is available, explore the option of a possible upgrade.
Conclusion:

We have demonstrated the ability to capture, send data wirelessly and reconstruct any analog signal. We have also proved that the radios have a range of at least 1.5 mile. This range can be extended by using different antennas. The wirelessly sent signals can be processed through LabVIEW. Our design is scalable for applications in medical field, construction industry and household applications.
Appendix A:

Compliance ISM band:  
\[ C:\Users\Anish\Desktop\Senior Design 2\compliance ism band.pdf \]

6020E User manual:  
\[ C:\Users\Anish\Desktop\Senior Design 2\6020Eusermanual.pdf \]

Ultiboard User Manual:  
\[ C:\Users\Anish\Desktop\Senior Design 2\Ultiboard User Manual.pdf \]

SC 2345  
\[ C:\Users\Anish\Desktop\Senior Design 2\sc2345.pdf \]

LM 7805  
\[ C:\Users\Anish\Desktop\Senior Design 2\LM7805.pdf \]

MAX186-MAX188  
\[ C:\Users\Anish\Desktop\Senior Design 2\MAX186-MAX188.pdf \]

LabVIEW getting started  
\[ C:\Users\Anish\Desktop\Senior Design 2\LV_Getting_Started.pdf \]

C8051  
\[ C:\Users\Anish\Desktop\Senior Design 2\C8051F34x.pdf \]

Radio User manual:  
\[ C:\Users\Anish\Desktop\Senior Design 2\4790User Manualv1.8.pdf \]