COMMUNICATION SYSTEM FOR THE REMOTE HYBRID POWER SYSTEM IN RAMEA NEWFOUNDLAND

JUAN FERNANDO ACEVEDO

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by

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ABSTRACT

A reliable communication system is essential for the operation of a remote hybrid power system. Such a system is needed to interconnect the wind turbines, diesel generators, and the hydrogen energy storage unit with a centralized supervisory controller and data acquisition system. For the purpose of this research, we have considered the remote wind-diesel-hydrogen hybrid power system currently under development at Ramea, Newfoundland. This thesis illustrates the implementation of a half-duplex collective transmission agreement with low RF transceivers and Power Line Carrier modems which allows the system to have a redundancy network and provide uninterrupted communication between the wind turbines and the main power building. Power line couplers with high pass filters and high frequency amplifiers are also designed and implemented to permit data transmission through high voltage power lines without affecting the performance of the data acquisition system. The research also provides the description of wind turbines parameters being measured at Ramea's remote hybrid power solution.

ACKNOWLEDGMENTS

I would like to thank Dr. Tariq Iqbal for his continuous guidance and support, the National Science and Engineering Research Council (NSERC) Wind Energy Strategic Network and Memorial University of Newfoundland for the financial support for this research. I would also like to thank Newfoundland and Labrador Hydro for providing site access and system data.

TRIBUTE

I would like to dedicate my work to my parents for their constant and unconditional support, to my family and friends for encouraging me in times of weakness.

"The ultimate challenge is in my mind"

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LIST OF ABBREVIATIONS AND SYMBOLS

AC:	Alternate Current
BPL:	Broadband over PowerLines
CAN:	Controller Area Network
DAS:	Data Acquisition System
DAST:	Data Acquisition System Transmitter
DSL:	Digital Subscriber Line
EMF:	ElectroMagnetic Field
FHSS:	Frequency Hopping Spread Spectrum
FSK:	Frequency Shifting Keying
FSO:	Free Space Optical
GUI:	Graphic User Interface
HFA:	High Frequency Amplifier
HPF:	High Pass Filter
ICD:	Inductive Coupling Device
ISM:	Industrial Scientific Medical
ISO:	International Organization for Standardization
LAN:	Local Area Network
MIMO:	Multiple Input Multiple Output
MPCB:	Main Power Control Building
MPCBR:	Main Power Control Building Receiver

PLC:	Power Line Carrier
RC:	Resistor Condenser
RF:	Radio Frequency
SCADA:	Supervisory Control And Data Acquisition
TCP/IP:	Transmission Control Protocol/Internet Protocol
USART:	Universal Synchronous/Asynchronous Receiver/Transmitter
USB:	Universal Serial Bus
UTP:	Unshielded Twisted Pair
WHD:	Wind Hydrogen Diesel
Wi-Fi:	Wireless Fidelity
WIMAX:	Worldwide Interoperability for Microwave Access

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CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

Isolated power systems on rural communities have been diesel dependent for decades not only to maintain residents' power demands but because of topography challenges they are unable to connect to main power grids. Nevertheless, fossil fuels' continuous cost growth and carbon emissions have made rural power plants shifted from diesel to a combination of renewable energy technology and diesel engines. Having evolved into hybrid power systems, energy grid's control system demands a constant and reliable communication not only to monitor and control selected carbon free sources of energy but to maintain a balanced distribution on power demand.

1.1 WIND-DIESEL HYBRID POWER SYSTEMS WORLDWIDE

Renewable energy systems can be a sustainable energy source guaranteeing reliability, sustainability, and affordability, but because of their natural characteristics they often have an intermittent energy source which requires complex techniques for optimal utilization. As a counter measure to potential power outages, hybrid power systems provide a higher level of stability with a combination of several carbon-free energy sources like wind or solar and non-renewable sources like diesel or natural gas. Remote power system categories are shown in Table 1.1.

Table 1.1. Isolated power system categories [1]

Installed Power (MW)	Category
<0.001	Micro System
0.001 – 0.1	Village Power System
0.1 – 10	Island Power System
>10	Large Interconnected System

Implementation of these hybrid systems has spread worldwide, countries like Australia, Canada, China, Greece, Norway, UK, USA and others, are increasingly growing their hybrid solutions in order to address global challenges such as carbon emission crisis, fuel flexibility, power efficiency, and economic growth among others. T. Ackerman [1] analyzes the history of hybrid power systems, their categories depending on power capacity, and illustrates a list of hybrid power systems installed in Sal, Cape Verde; Mindelo, Cape Verde; Dachen Island, China; Kythnos, Greece; Lemnos, Greece.

Table 1.2 shows a selection of some wind-diesel solutions installed around the globe, the technical data was retrieved from several references such as Meridian Energy [2], a report containing technical information about Ross Island, Antarctica hybrid energy system. S. Bennett [3] shows a chronological expose of Ross Island's (Antarctica) Wind Energy project progress report up to Dec 2009. The Renewable Energy Alaska Project reports [4]-[5] illustrate technical data about hybrid power projects in Summit station (Greenland), Kotzebue Alaska (USA), Guantanamo (Cuba), Ross Island (Antartica), St. Paul Alaska (USA), Coral Bay (Australia). The National Renewable Energy Laboratory

[6] presents power capacity information and wind penetration data of the hybrid power system in Mawson, Antarctica. J. Zimmerman [7] and D. Clarke's [8] research has information about isolated renewable energy/diesel systems installed in Bremer Bay, Cocos Island, Denham, Esperance, Hopetoun, Graciosa, Flores, Rottnest, and Ross Island in Australia. P. Lundsager et al. [9] reports technical information about hybrid power systems installed in: Sal and Mindelo (Cape Verde), La Desirade (Guadeloupe), Marsabit (Kenya), Cape Clear Island and Rathlin Island (Irland), Froya (Norway).

Table 1.2. List of Some Wind-Diesel Hybrid Power Systems

Country or Region	Site	Diesel Power (MW)	Wind Power (MW)	Avg. Load (MW)	Commissioned	Inst. Wind Penetration
Antarctica	Mawson	0.48	0.6	0.53	2002	34% (avg)
Antarctica	Ross Island	3	0.99	1.75	2010	70%
Australia	Bremer Bay	1.25	0.6		2005	>80%
Australia	Cocos Island	1.28	0.08		2005	15% (avg)
Australia	Coral Bay	2.24	0.825		2007	>90%
Australia	Denham	1.6	1.2		1998	>50%
Australia	Esperance	14.5	5.6		2003	>22%
Australia	Hopetoun	2.56	1.2		2004	>90%
Australia	Graciosa	3.2	0.8			60% (avg)
Australia	Flores	4	0.6			>50%
Australia	Rottnest	1.3	0.6		2006	37% (avg)
Canada	Ramea	2.78	0.69	0.7	2004	10% (avg)
Cape Verde	Sal	2.82	0.6	0.56		14% (avg)
Cape Verde	Mindelo	11.2	0.9	1.9		14% (avg)
China	Dachen Island	10.44	0.185			15% (avg)
Cuba	Guantanamo	22.8	3.8	12.5	2005	25%
Greece	Kythnos Island	2.774	0.315			
Greece	Lemnos Island	10.4	1.14			
Greenland	Summit	0.2	0.06			16%
Guadeloupe	La Désirade	0.88	0.14			40%
Kenya	Marsabit	0.3	0.15			46% (avg)
Norway	Frøya	0.05	0.055			100%
Ireland	Cape Clear Island	0.072	0.06			70%

Country or Region	Site	Diesel Power (MW)	Wind Power (MW)	Avg. Load (MW)	Commissioned	Inst. Wind Penetration
Ireland	Rathlin Island	0.26	0.99			100%
USA	St. Paul, Alaska	0.3	0.22	0.12	1999	68.5% (avg)
USA	Kotzebue, Alaska	11	1.14	1.37		50%

1.1.1 Canada's Wind Power Capacity

Although Canada has made a remarkable effort on expanding its national wind power capacity as seen in Table 1.3, there has been little progress with hybrid power systems development. According to J. Macgillivray [10] and the news reports [11]-[13] the Toktoyaktuk Wind–Diesel project will save 88,000 liters of diesel per year and will offset 247 tones of emissions year long.

According to the research done by T. M. Weis and A. Ilinca in 2007 [14] there have been several low-penetration wind-diesel systems installed across remote Canadian communities like Big Trout Lake (ON), Cambridge Bay (Nunavut), Ellesmere Island (Nuanvut), Fort Severn (ON), Igloolik (NT), Iqaluit (Nunavut), Kasabonika Lake (ON), Kugkluktuk (Nuanvut), Kuujjuaq (PQ), Omingmaktok (NT), Sachs Harbour (NT), Rankin Inlet (Nunavut) and Winisk (ON), but only Cambridge Bay and Kuujjuaq hybrid power systems where operational for 8 years, the rest had a maximum life span of 2 years.

Other initiatives like PEI's Energy Corporation [15] or B. Saulnier and R. Gagnon [16] are new Canadian developments on hybrid power systems. Projects like Nalcor Energy "Wind–Hydrogen–Diesel (WHD) Power System" in Ramea NL, Northern Wind

Tuktoyaktuk's project, PEI Wind-Hydrogen Village and Quaqtaq's studies are some of the major research contributions to the few Canadian national efforts to provide rural communities with efficient and cleaner sources of energy in order to reduce carbon emissions as a counter measure to global warming and fossil fuel economic challenges.

Technical data from Table 1.3 was retrieved from the Canadian Wind Energy Association (CANWEA) [17] [18] studies; the reports show graphs and tables explaining province's wind installed capacity and the Canadian wind energy projects with a signed power purchase agreement and/or already under construction/construction plan in place as of Aug. 24, 2010.

Table 1.3. Canada's current wind farm capacity

Province	Installed Capacity (MW)	Planned /Under Construction (MW)
Alberta	884	1039.6
British Columbia	103.5	711.2
Manitoba	104	138
New Brunswick	249	163.5
Newfoundland and Labrador	54.7	
Nova Scotia	214	185.55
Ontario	1,447	4032.1
Prince Edward Island	164	10
Quebec	663	2361
Saskatchewan	171.2	54.75
Yukon	0.81	
TOTAL	**4055.21**	**8695.7**

1.2 WIND-HYDROGEN-DIESEL (WHD) POWER SYSTEM OF RAMEA, NEWFOUNDLAND

Located six (6) kilometers South-West of Newfoundland, Ramea is an island community of 600 residents, its Hybrid Power System, shown in Figure 1.1, has a 2.775MW diesel plant consisting of three 925kW diesel generators and six 65kW wind turbines located North-West of the island added to the system by Frontier Power Systems (http://www.frontierpower.com).

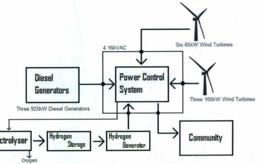


Figure 1.1. Current Ramea WHD Power System

According to "Ramea Wind-Hydrogen Diesel Project" 2007 progress report done by Newfoundland Hydro (http://www.nlh.nl.ca/) (a Nalcor Energy company), the development of the hybrid power project was undertaken by Nalcor Energy (http://www.nalcorenergy.com), they upgraded it in 2009 with three new 100kW wind turbines sited north of the Island and a Hydrogen facility currently under development [19]. Their power infrastructure combines wind, hydrogen, and diesel generators in order reduce the isolated community dependence on diesel and replace it with energy generation from a renewable resource.

Figure 1.2. Six (6) 65kW Wind Turbines

In September of 2004, Newfoundland Hydro began purchasing wind energy from Frontier Power's wind turbines (WindMatic WM15S, see Figure 1.2) which can have a combined wind penetration of 10% and offsets approximately 750 tones of emissions annually. The new three 100kW wind turbines installed by Nalcor Energy were positioned 130m, 200m, and 270m (see Figure 1.3) from the Main Power Control Building (MPCB). Nalcor Energy's winter 2010 "Ramea Report" mentions that the new wind turbines were commissioned in December 2009 and generated energy on the Ramea grid for the first time on May 8, 2010 [20].

Figure 1.3. Three (3) 100kW Wind Turbines

With Frontier Power's wind turbines Data Acquisition System (DAS) located 1.6km of the Main Power Control Building, the only remote connection currently installed is a wireless link between the DAS and the MPCB by the use of two Cirronet HN-210D transceivers. Unfortunately they are constantly having communication failures, especially during winter season. According to the HN-210 datasheet, its functional frequency is 2.4GHz ISM band which allows them to operate in the free-license electromagnetic spectrum [21]. The problem relies in transmitting under hazardous weather conditions like snow storms, rain, hail, or a combination of all three, limiting remote supervision and control; a 2.4GHz transmission is vulnerable to atmospheric attenuation. A reliable and low cost communication solution must be engineered in order to have a trustworthy control of Ramea's Hybrid Power System.

A communication system prototype for the remote WHD hybrid power system currently under development at Ramea, Newfoundland is presented in this document which motivation and focal points involve a cost-effective solution to maintain reliable and uninterrupted data transmission throughout the power grid, no modification on current power infrastructure, a combination of different communication methods working in sync for superior transmission stability, and comparison of commonly preferred techniques which will highlight the advantages and usefulness of this project. The proposed system is based on hybrid transmission between a wireless connection and data communication through existing power lines.

In chapter 2, hybrid power systems' communication methods are evaluated in order to have a broad analysis of the engineering involve in this thesis. In chapters 3 and 4, system prototype features and advantages are introduced, engineering design is explain in detail, and finally lab results and cost-effective solutions are studied for evaluation purposes. Conclusions and recommendations are discussed in chapter 5 for possible future development of the project.

CHAPTER 2: COMMUNICATION METHODS FOR HYBRID POWER SYSTEMS

Hybrid power solutions are always demanding trustworthy communications between renewable and non-renewable power systems to facilitate supervision and control of carbon free sources of energy and maintain a balanced distribution on power demand. In order to accomplish a constant and reliable communication link, numerous technologies need to be evaluated based on performance under any weather condition, transmission security, dedicated physical layer dependence, cost-effective solution, bandwidth capabilities, among others. The study will focus on technologies like Fiber Optic, FSO, CAN Bus, Wi-Fi, WIMAX, Low RF links, and PLC.

Table 2.1 shows a sample of analog & digital parameters measured to run proper diagnostics on wind turbine performance, statistical analysis, historical data record, updates on weather changes, remote control, dynamic warnings, and other features needed for the hybrid power system's Supervisory Control And Data Acquisition (SCADA). A suitable and reliable physical layer of communication is indeed needed for un-interrupted remote recording of these parameters, A. L. Pereira in 2000 studied methods like Parallel ports, Universal Serial Bus (USB), and Ethernet LAN for "Modular supervisory controller for hybrid power systems" [22]. R. Sebastian, M. Castro, E. Sancristobal, F. Yeves, J. Peire, and J. Quesada in 2002 proposed in their research "Approaching hybrid wind-diesel systems and Controller Area Network" a CAN Bus as a suitable implementation for hybrid wind-diesel systems [23]. Ramea's power system communication network relies on Fiber Optic and RF wireless transceivers, but there is no mention (wireless communication excluded) of a non invasive technique that does not require modifying the infrastructure such as Power Line Carrier or PLC which can be adjusted to meet this requirement.

Table 2.1 was sampled from Newfoundland Hydro's "Ramea Wind-Hydrogen-Diesel Project, Realistic Point Count for EMS Group – St. John's" report. They provided the hard copy in February 2009 so please refer to Appendix A for full scanned table content.

Table 2.1. Wind Turbine's analog and digital recorded data and sampling time

WindMatic WM15S	Unit	Point Type	Scan Rate
Inverter Power	kW	Analog	10s
Rotor Speed	RPM	Analog	10s
Inst. Wind Speed	m/s	Analog	10s
One Min.Avg Wind Speed	m/s	Analog	10s
Ten Min.Avg Wind Speed	m/s	Analog	10s
Hours Online		Analog	10s
Cumulative Energy Production	kWh	Analog	10s
Breaker Status	Open/ Closed	Digital	10s
Permission to Operate	Yes/No	Digital	10s

2.1. FIBER OPTIC

In recent years, Fiber Optic has become more appropriate for high speed data communication. The use of optic light pulses through the fiber lines instead of electronic pulses makes it unaffected to electromagnetic interferences, and with proper thermoplastic over-coating insulation it can be suitable to transmit under extreme weather conditions as mentioned in 1994 by H. Kirkham et al. [24]. Figure 2.1 below (retrieved from Home Theater Accessories Resource commercial webpage "How Optical Cable Works" [26]) shows the composition of an optical cable, Mary Bellis' article on "The birth of fiber optics" explains that a Fiber optic cables are optic wires inside an outer insulation that transmit digital information using light waves traveling by internal reflection over longer distances than any other high speed wired form of communication [25].

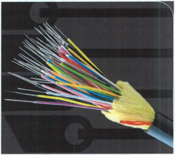


Figure 2.1. Optical Fiber Cable

Fiber optic networks can handle high speed data transmissions (up to several Gigabytes) and has been used for the communication network of the new three (3) 100kW wind turbines at Ramea. Even do the current fiber optic cables connecting these wind turbines to the MPCB allow them to reach Gbps transmissions, Table 2.1 above shows that the parameter scan rate does not require high bandwidth capability. Inconveniences like elevated costs and installation makes fiber optic not suitable for Ramea's hybrid power system. According to Newfoundland Hydro, CAN$19,380.00 was the estimated cost for only the fiber optic cables and considering expanding this network to the 65kW wind turbines' DAS will not fulfill the low budget aspiration of this project.

2.1.1 Free Space Optical

Emulating a Fiber Optic communication in a wireless environment could be another approach. A. Akbulut, H. Gokhan Ilk, F. Ari in 2005 mention in their study "Design, Availability and Reliability Analysis on an Experimental Outdoor FSO/RF Communication System**"**, that a Free Space Optical (FSO) technology can provide a 155Mbps full duplex connection, but the FSO devices have to be carefully installed in specific locations as they need a "Line-of-sight alignment", and data transmission is very susceptible when exposed to poor weather conditions [27]. This option is also not suitable for Ramea because of its low performance during poor weather conditions and since line of site transmission is not possible due to a hill between wind turbines' DAS and the diesel plant (Figure 2.2).

Figure 2.2. Hill between the DAS and MPCB

2.2. CONTROLLER AREA NETWORK (CAN) BUS

In 1986, the German company BOSCH developed CAN initially as a communication protocol for automotive applications. Shortly after, it was standardized in the International Organization for Standardization ISO 11898 & 11519 allowing the protocol to be used in a wide variety of networking devices including automotive, naval, medical and industrial applications as mentioned in Renesas Electronics Corporation "Introduction to CAN" study on CAN's outline, protocol, features, and standard specifications [28].

For a small overview of this communication method please refer to Renesas Electronics Corporation's "CAN connection diagram" on Figure 2.3 below, the CAN Controller decides the bus level (Dominant or Recessive) by the potential difference between the two cables (the "Bus"), connected transmitters send signals to the receiver by altering these levels. If two or more devices transmit at the same time, the CAN Controller will decide which signal pass first depending on their priority status.

Even though the 2002 study of "Approaching hybrid wind-diesel systems and Controller Area Network" mentions some advantages to the usage of a CAN Bus like switching from centralized to distributed control and minimum wiring, this communication method still needs a dedicated physical layer, an antagonistic feature to the un-modified power infrastructure attribute of this research. Additionally, the CAN Bus dependence on clock synchronization is an unnecessary feature that can be avoided with other communication technologies.

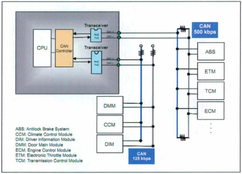


Figure 2.3. Classic CAN connection diagram

2.3. WIRELESS ETHERNET

Since the beginning of the 21st century, wireless networks have been exponentially growing and constantly required for faster Ethernet & Internet access. Cheaper installation expenses and total independency from physical Ethernet ports are the most attractive features in wireless communications.

Low budget commercially available wireless Ethernet modem/routers that uses the IEEE 802.11g or 802.11n standard work in the 2.4, 3.6 and 5 GHz frequency bands and a usual bit rate of 54Mbps (modems that uses IEEE802.11n standard can achieve up to 600Mbps), and its outdoor transmission varies from 100m-420m without compromising their bandwidth capabilities. Intel Corporation's article on "Helping Define 802.11n and other Wireless LAN Standards" states that increasing the throughput can be achieved by using the technology referred to as Multiple-Input-Multiple-Output (MIMO) which utilizes multiple signals from an array of antennas across a designated area [29], but this means a bigger investment to purchase signal repeaters. These modems are discarded for this project due to their dependence on present conditions and their limited outdoor communication range.

2.3.1 Worldwide Interoperability for Microwave Access (WIMAX)

Another possibility could be the use of WIMAX, a wireless telecommunication technology that uses the IEEE 802.16 standard, provides mobile internet access, around 40Mbps bandwidth, and operates under licensed spectrum owned by wireless service providers. According to Intel Corporation's study on "How WIMAX works", mobile WIMAX base stations over metropolitan size areas can provide wider coverage than Wi-Fi networks (up to two kilometers depending on terrain), and used commonly as a *last mile* wireless broadband replacement for Digital Subscriber Line (DSL) [30]. Nevertheless, the transmission is outside the unlicensed electromagnetic spectrum so there has to be a contract involved with a WIMAX carrier. Therefore, it would be a costly solution for hybrid power systems.

2.4. LOW RF TRANSCEIVERS

Transceiver is a device that has the capability to transmit and receive within the same circuitry. RF Transceiver uses Radio Frequency modules usually for high speed bps transmission, a wireless approach to LANs, but under extremely hazardous weather conditions like snow or hail storms common in Ramea during winter season, wireless transmission frequency band must be in sub-GHz. From Dr. J. Takei's analysis on "Digital Wireless Communication Basics: Overview of basic concepts", it is conceptualized that RF transceivers employing frequencies close to 900MHz makes them perfect to transmit even in extremely bad weather conditions as no attenuation and RF wave scattering is generated by snow or rain drops [31].

Even though the bit rate is lower than the Wireless Ethernet modems, they are very appropriate for Ramea's communication system as we could transmit data packages at low speed (57.6kbps) without affecting DAS performance. This data transfer rate can sustain Ramea's current wind farm remote supervision and control.

2.5. POWER LINE CARRIER

Power Line Carrier (PLC) or Power Line Communication technology incorporates high frequency signals traveling throughout power networks to dedicated PLC receivers distributed among the same complex. Using electric power transmission conductors as communication media will achieve a bidirectional data communication saving resources without installing new dedicated cabling. Applications for this technology include D. D. Bois, Energy Business "Broadband over Powerlines (BPL) in a Nutshell", which provides on-site users with high speed internet access through regular power outlets [32], and "Home Automation" [33] technology that allows house residents to control lights & appliances remotely using PLC modules such as: NETGEAR [34], X10 [35], LonWorks [36], INSTEON [37], EHS (European Home Systems) [38], KNX PL 110 [39], among others.

Above applications focus on domestic use (commonly 120-240VAC power lines) but to successfully transmit data through high voltage cabling (>1kVAC), without damaging microcontrollers or other low voltage devices, there has to be a proper installation of stage circuitry such as: Dedicated PLC modems connected to microcontrollers, a coupling and filtering stage between the modems and high voltage carriers, and a final synchronization process with the high voltage signal. The purpose is to have a bilateral communication between the DAS and the MPCB without modifying the power system infrastructure currently in place at Ramea.

In order to achieve a constant transmission, a redundant communication network can be accomplished if PLC operates as primary link and low RF transceivers as backup. Using PLC as primary is based on continuous presence of the power line cable, it is usually available the 24h of any giving day as it is permanently connected from DAS to the MPCB but if a miscommunication occurs then the wireless link will become enabled for data transmission. By implementing PLC and low RF transceivers we can achieve a reliable low cost communication system for control and data acquisition of Ramea's hybrid power system.

The rationale to opt for PLC & Low RF transceivers instead of the others is based on the previous analysis of above technologies. PLC & Low RF have economically feasible modems, accurate transmission capabilities under any weather condition, embedded wireless transmission encryption, no dedicated physical layer, redundant communication capabilities as a hybrid comm. system, the capability for future expansion to more than a pair of modules with the same type of modems, and bandwidth capabilities necessary for Ramea's WHD power system. Details of proposed communication system are provided in the next two chapters.

CHAPTER 3: COMMUNICATION SYSTEM FOR RAMEA'S HYBRID POWER SYSTEM

The communication system design is based primarily on transmission continuity and reliability, that is why the DAS-MPCB network will have two different types of technologies, the PLC system will be setup as primary and wireless link as backup. Low budget Netgear XE102 PLC modems can accomplish a safe communication with a modified coupling stage that will allow a safe link to the existing high voltage carrier (4.16kVAC). This modems use TCP/IP protocol and has LAN compatibility matching the necessary requirements for a remote access and network management from Newfoundland Hydro's control centre in St. John's, NL.

For the wireless link, LaridTech AC4790 transceivers are suitable for Ramea's atypical weather. Its datasheet stipulates a functional frequency variance between 902-928 MHz, a serial interface, enhanced interference rejection, an enabled co-located system operation with increased output power and data integrity [40]. Preliminary field testing demonstrated that successful transmission can be achieved at a maximum distance of 2.01km under optimal (no rain, hail or snow) weather conditions and no line of sight.

3.1. TRANSMISSION ALGORITHM

Figure 3.1 shows the transmission algorithm that the Data Acquisition System Transmitter (DAST) follows. The DAST emulates receiving data from wind turbine parameters mentioned in Table 2.1 and then they are sent primarily through the PLC; the

Main Power Control Building Receiver (MPCBR) then replies an acknowledgement signal which finally closes the DAS-MPCB communication loop. Failure to do so, the DAST recognizes this as a communication breakdown and re-transmits the same information through the wireless link and wait for the MPCBR to acknowledge the data. Whenever a new data package is ready for transmission, the DAST will send it again through the PLC and wait for the MPCBR's reply, if the MPCBR fails again the DAST will try to close the communication loop through the wireless link. Please refer to Appendix B for microcontroller's source code.

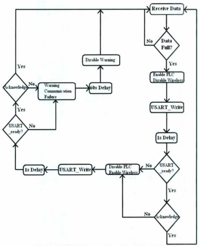


Figure 3.1. DAST Transmission Flow Chart [41]

3.2. COMMUNICATION SYSTEM SETUP

Figure 3.2 illustrates the complete communication system with the two communication prototypes.

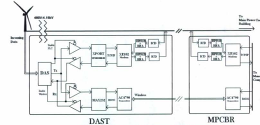


Figure 3.2. Communication System Diagram [42]

The microcontroller (PIC16F873A) or DAS serial interface (refer to Appendix E for full DAST schematic) is connected to a gate controlled TTL buffer (SN74ABT125) setup that allows the DAS to administrate the desired transmission link (see Figure 3.3). While the AC4790 needs RS232 protocol (MAX232ACPE), the PLC modem (Netgear XE102) needs TCP/IP, so a Serial-to-Ethernet adaptor (XPORT XP1001000-03) is used to connect the buffer setup to the XE102, this enhances the DAS-MPCB link with independent protocols for the two communication carriers. The AC4790 receives the data through RS232, adjust the signal with a FHSS FSK modulation, and sends it to the MPCBR. On the other hand, the Xport adaptor receives the data using the RS232 serial interface (CMOS Asynchronous, 5V Tolerant), and sends to the XE102 modem using TCP/IP protocol. Please refer to Appendix E for DAST's schematic diagram, each stage is explained in subsequent sections.

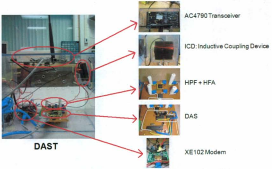


Figure 3.3. Data Acquisition System Transmitter Prototype Setup [42]

3.2.1. DAST's Microcontroller Pin Configuration

Table 3.1 describes the purpose and application for each of the PIC16F873A pins considering the following classification: NC: Not Connected; I: Input; O: Output; TTL: Transistor-Transistor Logic Input/Output; ST: Schmitt Trigger Input/Output; P: Power.

Table 3.1. DAST's Microcontroller PIC16F873A Pin Configuration

Name	Pin #	Type (I/O/P)	Buffer Type	Description
MCLR/Vpp	1			RESET
RA0/AN0	2	-	TTL	NC
RA1/AN1	3	-	TTL	NC
RA2/AN2/VREF-/CVREF	4	-	TTL	NC
RA3/AN3/ VREF+	5	-	TTL	NC
RA4/T0CKI/C1OUT	6	-	ST	NC
RA5/AN4/SS/C2OUT	7	-	TTL	NC
Vss	8	P	-	GND
OSC1/CLKI	9	I		Crystal oscillator
OSC2/CLKO	10	O		Crystal oscillator
RC0/T1OSO/T1CKI	11	-	ST	NC
RC1/T1OSI/CCP2	12	-	ST	NC
RC2/CCP1	13	-	ST	NC
RC3/SCK/SCL	14	-	ST	NC
RC4/SDI/SDA	15	-	ST	NC
RC5/SDO	16	-	ST	NC
RC6/TX/CK	17	O	ST	Serial Tx
RC7/RX/DT	18	I	ST	Serial Rx
Vss	19	P	-	GND
VDD	20	P	-	5V
RB0/INT	21	-	TTL/ST	NC
RB1	22	O	TTL	PCL High frequency buffer control
RB2	23	O	TTL	Wireless High frequency buffer control
RB3/PGM	24	O	TTL	LED control – Green
RB4	25	O	TTL	LED control – Red
RB5	26	-	TTL	NC
RB6/PGC	27	-	TTL/ST	NC
RB7/PGD	28	-	TTL/ST	NC

3.2.2. Serial-to-Ethernet Adaptor (XPORT XP1001000-03)

Lantronix, Inc. "XPort Embedded Device Server" is used to link DAST's PIC16F873A to the XE102, its function is to adjust microcontroller's TTL data to TCP/IP protocol and transmit them to the PCL modem. Even though this device is relatively small (33.9mm long, 16.25mm wide, 13.5mm tall), it comprises a 4Mb flash memory, a 25MHz crystal oscillator, circuit reset feature, 5V serial interface, embedded UART (compatible with 300-921600bps transmissions), Ethernet technology up to 100Mbps, and an external RJ-45 jack connected to a UTP cable (See Appendix D for detail technical data) [43].

Once the XPORT is connected to a Local Area Network (LAN), a fixed IP address is assigned to it using the "DeviceInstaller" software, and finally Telnet or a Hyperterminal application is used for the pos-configuration process (UART setup for example).

The XPORT package comes with an extra tool called "Redirector" which can be used to create virtual ports for easier data access while programming the User Graphic Interface mention in the subsequent section 3.3.1.

3.2.3. Inductive Coupling Stage

According to the analyzed power distribution system at Ramea, the WM15S Wind Turbines generate 480V which is then converted to 4160V with a step-up transformer. A coupling stage is needed to allow a successful connection between the PLC modems and the 4.16kV power line. Note in Figure 3.2 that the coupling is performed after the 480:4.16kV step-up transformer in order to avoid transmission instability. V. Krishnan "Transformer Bypass Circuit" study on Power Line Communication applications, capacitive and inductive coupling methods for PLC modules and power line cables, are the baseline for The DAST and MPCBR setup with an active filter (High Pass Filter (HPF), plus High Frequency Amplifier (HFA)) and an Inductive Coupling Device (ICD) to ensure low frequency signal discrimination and proper signal propagation [44]. Refer to section 3.2.3.1, 2 & 3 for full HPF, HFA and ICD analysis. After the MPCBR recognizes the data the acknowledgement signal is sent back through the power line closing the bilateral communication cycle.

3.2.3.1. High Pass Filter (HPF)

One of the designs for active high pass filters are based on passive HPF followed by an HFA, first order Resistance & Capacitance (*R&C* or *RC*) filters (Figure 3.4) are designed to attenuate low frequency signals including the induced AC from the 4.16kVAC plus noise signals remaining only high frequency signals from the XE102 modem.

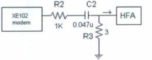


Figure 3.4. High Pass Filter

Measures and analysis from several samples of XE102 output demonstrated that its lowest frequencies are above 5MHz, as an example Figure 3.5 & 3.6 shows an instance of the sampled signal.

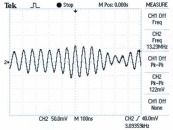


Figure 3.5. 1st Sample of Data Signal

Following high pass filter mathematical formulas found on A. S. Sedra & K. C. Smith "Microelectronic Circuits", the *R* & *C* values are based on a passive first order HPF with a -3db gain, which guarantees that low frequency signals are properly discriminated [45]. Cutoff frequency (f_c) of 1MHz is enough to acquire acceptable results:

Assuming $\omega = \omega_0$ (ω : angular frequency; ω_0 : cutoff frequency) (1)

Where $\omega = 2 * \pi * f$ (f : frequency) (2)

For a first order circuit $\omega_0 = \frac{1}{RC} \Rightarrow 2 * \pi * f = \frac{1}{RC}$ (3)

$$f = \frac{1}{(2 * \pi * R * C)} \tag{4}$$

Substituting $C = 0.47\mu F$ and $R = 3\Omega$

$$f = \frac{1}{(2 * \pi * 3\Omega * 0.047\mu F)} \approx 1MHz \tag{5}$$

3.2.3.2. High Frequency Amplifier (HFA)

After the high frequency signal passes the HPF a percentage is attenuated as seen in Figure 3.6. With the intention of matching the input signal shape while increasing the output, the High Frequency Amplifier seen in Figure 3.7 will correct the attenuation in order to have proper signal propagation by the ICD.

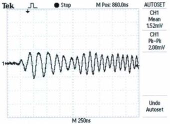


Figure 3.6. 2nd Sample of Data Signal

The HFA design is based on the LM6171, a high speed low power low distortion voltage feedback amplifier necessary for circuit requirements (datasheet on Appendix D); operates with 100MHz bandwidth, a supply voltage range of $\pm 36V$ and $\pm 5V$, and scope gain of 20-200.

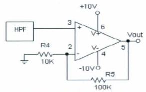


Figure 3.7. High Frequency Amplifier

3.2.3.3. Inductive Coupling Device (ICD)

In the late 1820s, Michael Faraday discovered that voltage is induced through a conductor moving through a magnetic field, or a magnetic field moving around a conductor. His law states that Voltage (*V* induced) is equal to the wire's number (*N*) of turns times magnetic flux over current (*I*) or:

$$V = N\frac{\Phi}{I} \tag{6}$$

The School of Physics in Sydney, Australia, states in their "Transformers" multimedia archive that Faraday's principle is followed if two coils are inductively coupled, converting ac power at a certain voltage level to ac power at a different level but same frequency; if there is a current change in one coil an ElectroMagnetic Field (EMF) is induced in other [46]. A high voltage pulse transformer was preliminary considered for the ICD to allow an interface between the low voltage devices and the 4.16kV power line, but lab tests showed that implementing the same transformer's concept to a less expensive iron core with a AWG 32 wire can work as the ICD induce the necessary signal for the coupling system to send/receive data through the power line. As shown in Figure 3.8, the high voltage cable passes through an iron core with an AWG 32 cable with 200 turns. From transformer's design we get the induction ratio (r):

$$r = \frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{200_S}{1_P} = 200 \tag{7}$$

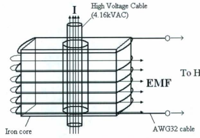


Figure 3.8. Inductive Coupling Device Diagram

The reason for the "high voltage cable pass through" design instead of spiraling it around the core is to model a non invasive ICD that will avoid disconnecting the power cable from its original installation, same principle as an inductive clamp.

As a counter measure to prevent unwanted signals passing to and from the inductive coupling stage, an inverted HPF was connected to the PLC modem input and ICD input as seen in Figure 3.9, therefore guarantying uncontaminated communication between the devices. Please refer to Appendix E for full DAST schematic.

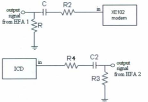
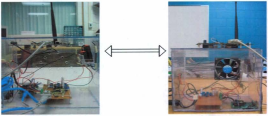


Figure 3.9. Inverted HPF

3.3. COMMUNICATION SYSTEM PROTOTYPES

Figure 3.10 shows the prototypes of above communication system; the DAST (left) has the wireless LaridTech AC4790 transceiver on top, PLC Netgear XE102 modem on the bottom left corner, and the ICD on the top right; the MPCBR has the wireless transceiver on top, PLC modem on the bottom right corner, the ICD on the top right, and a small cooling fan for heat removal purposes.



DAST
Data Acquisition System
Transmitter

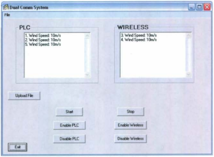
MPCBR
Main Power Control Building
Receiver

Figure 3.10. Communication System Prototypes

3.3.1. Graphic User Interface (GUI)

A Visual Basic GUI is designed to be operated by the user for data control and communication path supervision between the DAST and MPBCR. As seen from Figure 3.11 the user is capable to manually start/stop all transmissions or enable/disable each communication link individually, but there is an automatic background process which constantly scans for new incoming data, evaluates which comm. system was used, displays incoming data in real time, and transmits the acknowledgment signal through the same comm. link.

Since the DAST PLC modem is directly connected to the XPORT Serial-to-Ethernet adaptor, a TCP/IP virtual port is necessary for Power Line Communications while the computer serial port is used for wireless transmissions. Appendix C contains the Visual Basic source code.



1. Wind Speed: 10m/s
2. Wind Speed: 10m/s
5. Wind Speed: 10m/s

3. Wind Speed: 10m/s
4. Wind Speed: 10m/s

Figure 3.11. Graphic User Interface

For lab experimentation it is necessary to setup the DAST and MPCBR to an emulated 4.16kVAC power line so both ICD systems have to be coupled to a high voltage cable connected to four 120V-2kVAC transformers in series, two for each side. The GUI must be carefully supervised to display which communication medium was used for data transmission/reception and broadcast the acknowledgment signal through the same medium.

Going through above engineering design we have the PIC16F873A following its own algorithm which not only emulates receiving wind turbines parameters but will also controls the high frequency buffer configuration; the buffers are connected to the XPORT module and the MAX232, this last communicates with the AC4790 transceiver; the XPORT transmits the data to the XE102 modem which sends the data through an HPF, HFA, an inverted HPF, and finally through the ICD which induces the signal into the 4.16kVAC cable. To close the communication loop the GUI will use the MPCBR to acknowledge transmission as soon as it receives and displays wind turbine parameter data. Now the designed Communication System for the Remote Hybrid Power System in Ramea, NL is ready for experimental testing. Next chapter provides some experimental results.

CHAPTER 4. EXPERIMENTAL RESULTS

The microcontroller's algorithm, transmission synchronization, induced data reconstruction, acknowledgment of new acquired data and sub-stages were tested in sequence in order to isolate and resolve possible difficulties with the DAST, MPCBR, and GUI. Challenging conundrums like transmission synchronization with the high frequency buffers command controls as well as signal coupling, filtering and amplification were deeply examined in order to achieve optimal results.

Experimental testing results confirmed a successful DAS – MPCB communication as expected. Studies of these outcomes in addition to prototypes' cost analysis are documented as such:

- After testing numerous versions of the microcontroller's algorithm to solve synchronization difficulties with PLC-Wireless transmissions, it was necessary to first configure the microcontroller's USART and delay the primary transmission for 8s to let the XPORT module initialize, as well as creating a sub-routine that decontaminates the Rx USART buffer before transmitting through wireless as seen in Figure 4.1. Full source code can be found in Appendix B.

```
...

USART_init(57600);                    // initialize USART module
                                     //  (8 bit, 57600 baud rate, no parity bit...)
PORTB = 0;                          // Initialize PORT
TRISB = 0;                         // Configure PORTB as output
v = 1;                           // validate send / receive data
Delay_ms(8000);                      //Delay of 8s to let XPORT initialize

...

//---------------Start Empty trash can
   if (USART_Data_Ready())            // if trash data is received
   {
     trash_ = USART_Read();          // read the received trash data
   }
//---------------Finish Empty trash can

...
```

Figure 4.1. Microcontroller's Algorithm XPORT initialization + Buffer Decontamination

Laboratory tests determined that with above sub-routines the DAST can successfully communicate with the MPCBR and record data on a terminal computer via Ethernet without the loss of characters. Wireless and PLC signals had no instability and satisfactory transmission synchronization.

- As shown in Figure 4.2, the high pass filter, high frequency amplifier, and the 4.16kVAC inductive coupling overall performance is acceptable for an ideal PLC communication. The Inductive Coupling Device transfers the high (Data) and low (60Hz power AC voltage at lower scale) frequency signals to the active high pass filter (HPF+HFA), 60Hz sine wave is discriminated and only the data signal is amplified, then processed by the PLC modem, converted to TCP/IP and last the parameter is displayed on the GUI.

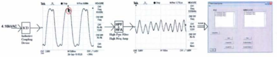


Figure 4.2. ICD & HPF+HFA Signal

Transmission rate analysis under laboratory conditions shows that it can reach up to 1Mb/20s which meets the necessary scan rate requirement predetermined by wind turbine parameters on Table 2.1.

4.1. COST – BENEFIT ASSESSMENT

Taking into consideration what is mentioned in Chapter 1.2, paragraph 4 about not using low cost transceivers with a 2.4GHz transmission which is vulnerable to atmospheric attenuation, plus Newfoundland Hydro's fiber optic initial expense of CAN$19,380.00 mentioned in Chapter 2.1; comparing it to what is shown in Table 4.1, a total hardware cost of CAN$443.60 can initially satisfy the low budget cost-effective goal of the project.

Table 4.1. Hardware Cost

Unit	Price ($CAN)
AC4790	$62.5(x2)
XE102	$99.00(x2)
PIC16F873A	$4.00

Unit	Price ($CAN)
MAX232	$0.50
SN74ABT125	$0.90
LM6171	$2.80(x4)
ICD	<$2.00(x2)
Miscellaneous	$100.00
TOTAL	**$443.60**

Considering that first prototype expense costs are always higher than the next ones, these modules can become even more economically attractive by reducing manufacturing expenditures if the DAST & MPCBR are to be conceived as mass production products for different kinds of hybrid power systems, a very convenient aspect for power companies.

4.1.1. Benefits

There are fundamental benefits which determine the feasibility, advantage, and purpose of this project such as:

- Establishing a new and efficient approach to supervise wind turbine performance without compromising existing hybrid power system infrastructure.
- Reducing expenses by adding a second purpose to existing power cabling currently installed.

- Minimizing communication failures attributable to hazardous weather conditions by establishing a redundant PLC-Wireless transmission.
- Limiting onsite travel to a minimum.
- A new incentive for engineers to innovate new practical products for current & future generation of hybrid power systems.
- Possibility for a new market in the hybrid power communication system industry.

Taking into account the benefits that this communication system provides, it creates a new innovative approach to today's hybrid power systems market.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The design of a Communication System for the Remote Hybrid Power System in Ramea, NL was not only challenging but insightful, studying the different types of hybrid power systems and their communication technologies provided us with a preliminary design that later on was engineered into an unconventional approach to communicate the different power systems. Hybrid communication for hybrid power systems combines the advantages of two different technologies working as one. Insights on these advantages are described below:

- The usefulness of implementing a half duplex transmission agreement with PLC and RF technologies combined is to assure the redundancy necessary for a constant and stable communication. A trustworthy remote transmission opens the possibility for automated systems to become more independent. Currently at Ramea the remote control is limited to a collective Enable/Disable of all wind turbines but future enhancements in wind turbine control's robustness will become possible with constant remote communication regardless of present weather conditions.

- Advantages like minimizing constant weather limitations will provide technicians with a reliable communication system for potential upgrades not only in remote supervision and control but faster technical response time on extraordinary circumstances like wind turbines malfunction, power cabling detachment, and data error transmissions.

- Implementing PLC modems and low RF transceivers to our system is not only an economically feasible approach to hardware communication expenses but can also reduce budget spending without allocating dedicated mediums to remote communication systems. Preserving Ramea's current power infrastructure will minimize system's downtime installation processes.

- Wireless enhancements to remote transmissions in addition to include extra tasks to existing power cabling with PLC will limit onsite travel to a minimum, therefore reducing fuel consumption, ground transportation maintenance, and traffic misfortunes.

- The Data Acquisition System Transmitter (DAST) was designed with the purpose of emulating the compilation of wind turbine parameter readings and resourcefully but yet efficiently transmit the data with low budget expenditure.

- Using a Serial-to-Ethernet XPORT adaptor allowed the microcontroller's TTL signal adaptation to TCP/IP corresponding to XE102 PLC modem's Ethernet protocol compatibility.

- A high frequency buffer arrangement was implemented for the DAST as a matter to synchronize two communication technologies attached to a single data acquisition system. The master control for the buffer arrangement was successfully programmed in the microcontroller which its inverse TTL outputs of pins 22 & 23 dictates which transmission is suppressed while enabling the other at the same time.

- The synchronization algorithm implemented to DAST's master transmission control was not only designed to be fully automatic but simple enough to be a recursive function with the limited amount of memory available in the microcontroller.

- Calibrating high pass filters and amplifiers for the inductive coupling stage was an overwhelming assignment with remarkable results that allowed the iron core induction device to send and/or receive suitable quality data. The retrieved signal was reconstructed with enough rigor to be duplicated in the Main Power Control Building Receiver (MPCBR) employing an equivalent circuitry.

- XE102 PLC modems where essential not only for data transmission through power lines but adding a special feature to the MPCBR, remote supervision anywhere in the Local Area Network. With proper routing network configuration the MPCBR data could be retrieved any where throughout the Worldwide Web.

- The Graphic User Interface (GUI) was designed to remotely recognize which communication method is currently been used for transmission, monitor and display the wind turbines parameters in real time as well as having user friendly features for communication control.

- Matters like weather insulation, overheating protection, and power overloads must be taken into consideration for future upgrades to the prototypes with the purpose of avoiding environmental, structural and personal hazards, otherwise the system can become a mayor safety risk to the infrastructure.

5.1. FUTURE WORK

Various recommendations are reported in this thesis for future improvement of the "Communication System For The Remote Hybrid Power System In Ramea Newfoundland" in order to adjust the prototypes to multiple hybrid power system infrastructure configurations:

- A battery backup system and power management algorithms must be designed to take advantage of a semi-independent feature like having a constant communication in case the power system is switched off for maintenance or cabling detachment from the main power network. For future references, on Table 4.2 below you will find the theoretical load consumption of each DAST device in order to maintain a wireless connection with the MPCBR:

Table 4.2. Load Consumption

Component	
AC4790	68mA
PIC16F873A	250mA
MAX232	8mA
SN74ABT125	64mA
Total Power Consumption:	**2.12W**

- Implementing a transformer bypass will eliminate the PLC constraint and transmit signal even if the DAST is connected before a main power transformer. An optical approach might be the solution to overcome this limitation, a low budget laser point at one side of the transformer can be modified to be used as a transmitter while a light-receiving device or diode is attached to the other side of the transformer, and with filters, amplifiers and ICDs, the signal can be re-adapted for PLC transmission. The light transmitter and receiver must be encapsulated on a dark/black cylindrical non metal tube to avoid losing data packages or transmission errors.

- Future studies on how to interface the prototypes with hybrid power system's centralized supervisory controller to analyze compatibility challenges.

- Implementation of a compatible encryption algorithm for the DAST and GUI to avoid a potential system cracking or data theft.

- Include a Log file for the GUI which automatically records date, time, source, communication path, and type of incoming data.

- Improve GUI to display all information from the Log file.

- Secure Routing configuration for data recording through the Internet.

- Modification to the prototypes' encapsulation boxes for easier transportation, smaller dimensions, and easier user friendly installation features.

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APPENDIX A. RAMEA WIND-HYDROGEN-DIESEL PROJECT, REALISTIC POINT COUNT FOR EMS GROUP – ST. JOHN'S

RAMEA WIND-HYDROGEN-DIESEL PROJECT
REALISTIC POINT COUNT FOR EMS GROUP - ST. JOHN'S
(Analog Point Count = 254, Digital Point Count = 178)

Point Description	Point Type	Status Update	Scan Rate
Analog Points			
Diesel Plant			
Diesel Plant On Line Capacity	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel Plant Off Line Capacity	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Minimum Diesel Plant Generation	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Renewable (Wind) Setpoint	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Town Load (kW)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Generation (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G1 Generation (kVAR)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Power Factor	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Frequency (Hz)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Energy Produced (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G1 Voltage Vab (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Voltage Vbc (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Voltage Vca (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Amperage Aph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Amperage Bph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Amperage Cph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Engine Hours	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G1 Fuel Flow (lit/hr)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Generation (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G2 Generation (kVAR)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Power Factor	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Frequency (Hz)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Energy Produced (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G2 Voltage Vab (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Voltage Vbc (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Voltage Vca (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Amperage Aph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Amperage Bph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Amperage Cph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Engine Hours	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G2 Fuel Flow (lit/hr)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Generation (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G3 Generation (kVAR)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Power Factor	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Frequency (Hz)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Energy Produced (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Diesel G3 Voltage Vab (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec

Diesel G3 Voltage Vbc (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Voltage Vca (Volts)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Amperage Aph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Amperage Bph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Amperage Cph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Engine Hours	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Diesel G3 Fuel Flow (lit/hr)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Feeder L1 Load (kW)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Feeder L2 Load (kW)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power			
Frontier Wind - WG1 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind - WG2 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind - WG3 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind - WG4 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind - WG5 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind - WG6 kW	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind Speed	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind Direction	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Wind Total Generation (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier Dump Load (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier Import Power (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier Export Power (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier VAR Import	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier VAR Export	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Energy Import (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier Energy Export (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Frontier Power Volt. A-B (kV)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power Volt. B-C (kV)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power Volt. C-A (kV)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power - Aph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power - Bph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power - Cph (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Vab (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Vbc (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Vca (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Ia (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Ib (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Frontier Power THD-Ic (%)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Meteorogical Site			
NLH Met Tower - 15m wind speed	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower - 20m wind speed	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower - 25m wind speed	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower Ambient Temp. 1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower Ambient Temp. 2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower Wind Direction 1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NLH Met Tower Wind Direction 2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec

H2 Storage Tank Facility			
H2 Tank 1 Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 1 Temperature	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 1 Storage Level	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 2 Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 2 Temperature	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 2 Storage Level	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 3 Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 3 Temperature	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tank 3 Storage Level	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tanks Outlet Flow	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tanks Outlet Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Tanks Inlet Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gensets - HEC			
H2 Genset Total kW Import	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Total kVAR Import	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Total kW Output	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Total kVAR Output	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Bus Volt (Vab)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Bus Volt (Vbc)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Bus Volt (Vca)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset THD - Voltage	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset THD - Current	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Frequency	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Amps (Aph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Amps (Bph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Amps (Cph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Voltage Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Main Current Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow to Gensets	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Header Pressure	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Power (kW) - G1	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Energy Produced (kWh) - G1	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Reactive Power (kVAR) - G1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow - G1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset RPM - G1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Power (kW) - G2	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Energy Produced (kWh) - G2	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Reactive Power (kVAR) - G2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow - G2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset RPM - G2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Power (kW) - G3	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Energy Produced (kWh) - G3	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Reactive Power (kVAR) - G3	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow - G3	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset RPM - G3	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec

H2 Genset Power (kW) - G4	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Energy Produced (kWh) - G4	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Reactive Power (kVAR) - G4	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow - G4	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset RPM - G4	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset Power (kW) - G5	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Energy Produced (kWh) - G5	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
H2 Genset Reactive Power (kVAR) - G5	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Mass Flow - G5	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Genset RPM - G5	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Unit No. 7			
Ion Meter - WG7			
NW100 kW Import - WG7	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Import - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 kW Output - WG7	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Output - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vab) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vbc) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vca) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 THD - Voltage - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 THD - Current - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Frequency Grid Side - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Aph) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Bph) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Cph) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Voltage Unbalance - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Current Unbalance - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Controller - WG7			
NW100 Inverter Power (kW) - WG7	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 Yaw Position wrt Center - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Rotor Speed (RPM) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Inst. Wind Speed (m/s) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 One Min.Avg Wind Speed (m/s) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Ten Min.Avg Wind Speed (m/s) - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Hours Online - WG7	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Cumulative Energy Production (kWh) - WG7	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 Unit No. 8			
Ion Meter - WG8			
NW100 kW Import - WG8	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Import - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 kW Output - WG8	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Output - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vab) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vbc) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vca) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 THD - Voltage - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec

NW100 THD - Current - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Frequency Grid Side - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Aph) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Bph) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Cph) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Voltage Unbalance - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Current Unbalance - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Controller - WG8			
NW100 Inverter Power (kW) - WG8	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 Yaw Position wrt Center - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Rotor Speed (RPM) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Inst. Wind Speed (m/s) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 One Min.Avg Wind Speed (m/s) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Ten Min.Avg Wind Speed (m/s) - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Hours Online - WG8	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Cumulative Energy Production (kWh) - WG8	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 Unit No. 9			
Ion Meter - WG9			
NW100 kW Import - WG9	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Import - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 kW Output - WG9	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 kVAR Output - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vab) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vbc) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Bus Volt (Vca) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 THD - Voltage - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 THD - Current - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Frequency Grid Side - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Aph) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Bph) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Grid Side Amps (Cph) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Voltage Unbalance - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Main Current Unbalance - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Controller - WG9			
NW100 Inverter Power (kW) - WG9	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
NW100 Yaw Position wrt Center - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Rotor Speed (RPM) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Inst. Wind Speed (m/s) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 One Min.Avg Wind Speed (m/s) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Ten Min.Avg Wind Speed (m/s) - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Hours Online - WG9	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
NW100 Cumulative Energy Production (kWh) - WG9	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Electrolyzer - Hydrogenics			
Ion Meter			
Electrolyzer Power Usage (kW)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
Electrolyzer Energy Consumption (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec

Electrolyzer kVAR Consumption	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Main Bus Volt (Vab)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Main Bus Volt (Vbc)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Main Bus Volt (Vca)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer THD - Voltage	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer THD - Current	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Amps (Aph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Amps (Bph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Amps (Cph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Voltage Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer Current Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Electrolyzer			
Power Setpoint value to Electrolzyer	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Pressure - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Electrolyte Level - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Temperature - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Production (NCMh) - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Pressure - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Electrolyte Level - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Temperature - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Production (NCMh) - CS1	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Current in Cell Stack 1 (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Pressure - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Electrolyte Level - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Separator Temperature - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Gas Production (NCMh) - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Pressure - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Electrolyte Level - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Separator Temperature - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Gas Production (NCMh) - CS2	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Current in Cell Stack 2 (Amps)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
H2 Total Production (NCMh)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
O2 Total Production (NCMh)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Ion Meter - S/G 52B3B1	Analog Register		
S/G kW Import	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
S/G kVAR Import	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G kW Output	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
S/G kVAR Output	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Net Energy Export (kWh)	Analog Register	Threshold Reporting - Deadband +/- 0.5%	10 sec
S/G Bus Volt (Vab)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Bus Volt (Vbc)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Bus Volt (Vac)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G THD - Voltage	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G THD - Current	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Frequency	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Amps (Aph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec

S/G Amps (Bph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Amps (Cph)	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Voltage Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
S/G Current Unbalance	Analog Register	Threshold Reporting - Deadband +/- 2%	10 sec
Digital Points			
Diesel Plant			
Plant in Overload Condition	Digital Status	Report by Exception	5 min poll
Diesel Plant Power Outage	Digital Status	Report by Exception	5 min poll
Main PLC Fail / Alarm (8 grouped)	Digital Status	Report by Exception	5 min poll
Low Starting Air Pressure (2 grouped)	Digital Status	Report by Exception	5 min poll
Diesel Gen. Incomplete Sequence - G1	Digital Status	Report by Exception	5 min poll
Diesel Gen. PLC Fail / Alarm (3 grouped) - G1	Digital Status	Report by Exception	5 min poll
Generator Status On/Off - G1	Digital Status	Report by Exception	5 min poll
Generator Mode Isoch/Base - G1	Digital Status	Report by Exception	5 min poll
Generator in Auto - G1	Digital Status	Report by Exception	5 min poll
Generator in Manual - G1	Digital Status	Report by Exception	5 min poll
Generator Breaker Status - G1	Digital Status	Report by Exception	5 min poll
Diesel Generator Fail to Remove - G1	Digital Status	Report by Exception	5 min poll
Diesel Generator Turbo Alarm (10 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Generator Winding Temp. Alarm (6 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Generator Coolant System Alarm (9 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Generator Drive Bearing Alarm (4 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Engine Exhaust Alarm (2 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Engine Oil Pressure Alarm (3 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Fuel Alarm (4 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Oil Temp Alarm (2 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Jacket Water Temp Alarm (2 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Engine Speed Alarm (2 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Fire Alarm - G1	Digital Status	Report by Exception	5 min poll
Diesel Air Box Alarm - G1	Digital Status	Report by Exception	5 min poll
Diesel Overcrank - G1	Digital Status	Report by Exception	5 min poll
Diesel Fail to Synchronize - G1	Digital Status	Report by Exception	5 min poll
Generator Protection Trip/Alarm (6 grouped) - G1	Digital Status	Report by Exception	5 min poll
Diesel Gen. Incomplete Sequence - G2	Digital Status	Report by Exception	5 min poll
Diesel Gen. PLC Fail / Alarm (3 grouped) - G2	Digital Status	Report by Exception	5 min poll
Generator Status On/Off - G2	Digital Status	Report by Exception	5 min poll
Generator Mode Isoch/Base - G2	Digital Status	Report by Exception	5 min poll
Generator in Auto - G2	Digital Status	Report by Exception	5 min poll
Generator in Manual - G2	Digital Status	Report by Exception	5 min poll
Generator Breaker Status - G2	Digital Status	Report by Exception	5 min poll
Diesel Generator Fail to Remove - G2	Digital Status	Report by Exception	5 min poll
Diesel Generator Turbo Alarm (10 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Generator Winding Temp. Alarm (6 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Generator Coolant System Alarm (9 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Generator Drive Bearing Alarm (4 grouped) - G2	Digital Status	Report by Exception	5 min poll

Diesel Engine Exhaust Alarm (2 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Engine Oil Pressure Alarm (3 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Fuel Alarm (4 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Oil Temp Alarm (2 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Jacket Water Temp Alarm (2 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Engine Speed Alarm (2 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Fire Alarm - G2	Digital Status	Report by Exception	5 min poll
Diesel Air Box Alarm - G2	Digital Status	Report by Exception	5 min poll
Diesel Overcrank - G2	Digital Status	Report by Exception	5 min poll
Diesel Fail to Synchronize - G2	Digital Status	Report by Exception	5 min poll
Generator Protection Trip/Alarm (6 grouped) - G2	Digital Status	Report by Exception	5 min poll
Diesel Gen. Incomplete Sequence - G3	Digital Status	Report by Exception	5 min poll
Diesel Gen. PLC Fail / Alarm (3 grouped) - G3	Digital Status	Report by Exception	5 min poll
Generator Status On/Off - G3	Digital Status	Report by Exception	5 min poll
Generator Mode Isoch/Base - G3	Digital Status	Report by Exception	5 min poll
Generator in Auto - G3	Digital Status	Report by Exception	5 min poll
Generator in Manual - G3	Digital Status	Report by Exception	5 min poll
Generator Breaker Status - G3	Digital Status	Report by Exception	5 min poll
Diesel Generator Fail to Remove - G3	Digital Status	Report by Exception	5 min poll
Diesel Generator Turbo Alarm (10 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Generator Winding Temp. Alarm (6 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Generator Coolant System Alarm (9 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Generator Drive Bearing Alarm (4 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Engine Exhaust Alarm (2 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Engine Oil Pressure Alarm (3 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Fuel Alarm (4 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Oil Temp Alarm (2 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Jacket Water Temp Alarm (2 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Engine Speed Alarm (2 grouped) - G3	Digital Status	Report by Exception	5 min poll
Diesel Fire Alarm - G3	Digital Status	Report by Exception	5 min poll
Diesel Air Box Alarm - G3	Digital Status	Report by Exception	5 min poll
Diesel Overcrank - G3	Digital Status	Report by Exception	5 min poll
Diesel Fail to Synchronize - G3	Digital Status	Report by Exception	5 min poll
Generator Protection Trip/Alarm (6 grouped) - G3	Digital Status	Report by Exception	5 min poll
Sub-system PLC Fail / Alarm (3 grouped)	Digital Status	Report by Exception	5 min poll
Battery / UPS Fault / Alarm (7 grouped)	Digital Status	Report by Exception	5 min poll
F1 Protection Trip	Digital Status	Report by Exception	5 min poll
F2 Protection Trip	Digital Status	Report by Exception	5 min poll
87/86OD Protection (4 grouped)	Digital Status	Report by Exception	5 min poll
General Fire Alarm (2 grouped)	Digital Status	Report by Exception	5 min poll
G1/G2/G3 Heat Valve Alarm (6 grouped)	Digital Status	Report by Exception	5 min poll
G1/G2/G3 Three Way Valve Alarm (6 grouped)	Digital Status	Report by Exception	5 min poll
G1/G2/G3 Water in Fuel Alarm (3 grouped)	Digital Status	Report by Exception	5 min poll
Frontier Power			
Frontier Breaker Status (open / closed)	Digital Status	Report by Exception	5 min poll
Frontier Permission to Operate	Digital Status	Report by Exception	5 min poll

EMS PLC			
Main EMS PLC Alarm	Digital Status	Report by Exception	5 min poll
NLH Met Tower Alarm (2 grouped)	Digital Status	Report by Exception	5 min poll
H2 Storage Tank Facility			
H2 Tank 1 Inlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank 1 Outlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank 2 Inlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank 2 Outlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank 3 Inlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank 3 Outlet Valve Status	Digital Status	Report by Exception	5 min poll
H2 Tank I/O Module Alarm	Digital Status	Report by Exception	5 min poll
H2 Tank Transmitter Alarm (8 grouped)	Digital Status	Report by Exception	5 min poll
H2 Gensets - HEC			
H2 Genset ION Meter Alarm	Digital Status	Report by Exception	5 min poll
H2 Genset Base Load Operation Status	Digital Status	Report by Exception	5 min poll
H2 Genset Isochronous Operation Status	Digital Status	Report by Exception	5 min poll
H2 Genset Main Breaker Status	Digital Status	Report by Exception	5 min poll
H2 Detected in Quonset Hut Status	Digital Status	Report by Exception	5 min poll
H2 Controller Alarm	Digital Status	Report by Exception	5 min poll
Fire / Smoke Alarm in Quonset Hut	Digital Status	Report by Exception	5 min poll
H2 Main Flow Valve Position	Digital Status	Report by Exception	5 min poll
H2 Genset Electrical Protection - G1	Digital Status	Report by Exception	5 min poll
H2 Genset Mechanical Protection - G1	Digital Status	Report by Exception	5 min poll
H2 Genset Controller Alarm - G1	Digital Status	Report by Exception	5 min poll
H2 Genset On/Off Status - G1	Digital Status	Report by Exception	5 min poll
H2 Genset Breaker Status - G1	Digital Status	Report by Exception	5 min poll
H2 Genset Electrical Protection - G2	Digital Status	Report by Exception	5 min poll
H2 Genset Mechanical Protection - G2	Digital Status	Report by Exception	5 min poll
H2 Genset Controller Alarm - G2	Digital Status	Report by Exception	5 min poll
H2 Genset On/Off Status - G2	Digital Status	Report by Exception	5 min poll
H2 Genset Breaker Status - G2	Digital Status	Report by Exception	5 min poll
H2 Genset Electrical Protection - G3	Digital Status	Report by Exception	5 min poll
H2 Genset Mechanical Protection - G3	Digital Status	Report by Exception	5 min poll
H2 Genset Controller Alarm - G3	Digital Status	Report by Exception	5 min poll
H2 Genset On/Off Status - G3	Digital Status	Report by Exception	5 min poll
H2 Genset Breaker Status - G3	Digital Status	Report by Exception	5 min poll
H2 Genset Electrical Protection - G4	Digital Status	Report by Exception	5 min poll
H2 Genset Mechanical Protection - G4	Digital Status	Report by Exception	5 min poll
H2 Genset Controller Alarm - G4	Digital Status	Report by Exception	5 min poll
H2 Genset On/Off Status - G4	Digital Status	Report by Exception	5 min poll
H2 Genset Breaker Status - G4	Digital Status	Report by Exception	5 min poll
H2 Genset Electrical Protection - G5	Digital Status	Report by Exception	5 min poll
H2 Genset Mechanical Protection - G5	Digital Status	Report by Exception	5 min poll
H2 Genset Controller Alarm - G5	Digital Status	Report by Exception	5 min poll
H2 Genset On/Off Status - G5	Digital Status	Report by Exception	5 min poll

H2 Genset Breaker Status - G5	Digital Status	Report by Exception	5 min poll
NW100 Unit No. 7			
NW100 BE1-1051 Alarm / Trip - WG7	Digital Status	Report by Exception	5 min poll
NW100 Inverter State - WG7	Digital Status	Report by Exception	5 min poll
NW100 Rectifier State - WG7	Digital Status	Report by Exception	5 min poll
NW100 Inverter Fault / Warning - WG7	Digital Status	Report by Exception	5 min poll
NW100 Rectifier Fault / Warning - WG7	Digital Status	Report by Exception	5 min poll
NW100 System Fault / Warning - WG7	Digital Status	Report by Exception	5 min poll
NW100 Turbine State - WG7	Digital Status	Report by Exception	5 min poll
NW100 Yaw State - WG7	Digital Status	Report by Exception	5 min poll
NW100 Brake State - WG7	Digital Status	Report by Exception	5 min poll
NW100 Turbine Available for Dispatch - WG7	Digital Status	Report by Exception	5 min poll
NW100 Controller Communication Fault - WG7	Digital Status	Report by Exception	5 min poll
NW100 Unit No. 8			
NW100 BE1-1051 Alarm / Trip - WG8	Digital Status	Report by Exception	5 min poll
NW100 Inverter State - WG8	Digital Status	Report by Exception	5 min poll
NW100 Rectifier State - WG8	Digital Status	Report by Exception	5 min poll
NW100 Inverter Fault / Warning - WG8	Digital Status	Report by Exception	5 min poll
NW100 Rectifier Fault / Warning - WG8	Digital Status	Report by Exception	5 min poll
NW100 System Fault / Warning - WG8	Digital Status	Report by Exception	5 min poll
NW100 Turbine State - WG8	Digital Status	Report by Exception	5 min poll
NW100 Yaw State - WG8	Digital Status	Report by Exception	5 min poll
NW100 Brake State - WG8	Digital Status	Report by Exception	5 min poll
NW100 Turbine Available for Dispatch - WG8	Digital Status	Report by Exception	5 min poll
NW100 Controller Communication Fault - WG8	Digital Status	Report by Exception	5 min poll
NW100 Unit No. 9			
NW100 BE1-1051 Alarm / Trip - WG9	Digital Status	Report by Exception	5 min poll
NW100 Inverter State - WG9	Digital Status	Report by Exception	5 min poll
NW100 Rectifier State - WG9	Digital Status	Report by Exception	5 min poll
NW100 Inverter Fault / Warning - WG9	Digital Status	Report by Exception	5 min poll
NW100 Rectifier Fault / Warning - WG9	Digital Status	Report by Exception	5 min poll
NW100 System Fault / Warning - WG9	Digital Status	Report by Exception	5 min poll
NW100 Turbine State - WG9	Digital Status	Report by Exception	5 min poll
NW100 Yaw State - WG9	Digital Status	Report by Exception	5 min poll
NW100 Brake State - WG9	Digital Status	Report by Exception	5 min poll
NW100 Turbine Available for Dispatch - WG9	Digital Status	Report by Exception	5 min poll
NW100 Controller Communication Fault - WG9	Digital Status	Report by Exception	5 min poll
Electrolyzer - Hydrogenics			
Electrolyzer - Emergency Stop	Digital Status	Report by Exception	5 min poll
Electrolyzer - H2 Detected in Process Room	Digital Status	Report by Exception	5 min poll
Electrolyzer - H2 Detected in Compressor Room	Digital Status	Report by Exception	5 min poll
Electrolyzer - O2 High Alarm Process Room	Digital Status	Report by Exception	5 min poll
Electrolyzer - 24V DC Alarm	Digital Status	Report by Exception	5 min poll
Electrolyzer - Master Basic Start Conditions OK	Digital Status	Report by Exception	5 min poll
Electrolyzer - Nitrogen Basic Start Cond. OK	Digital Status	Report by Exception	5 min poll

Electrolyzer - H2 Deoxo Dryer Start Cond. OK	Digital Status	Report by Exception	5 min poll
Electrolyzer - O2 Dehydro Dryer Start Cond. OK	Digital Status	Report by Exception	5 min poll
Electrolyzer - H2 Purge & Prod. Start Cond. OK	Digital Status	Report by Exception	5 min poll
Electrolyzer - Cell Stack 1 Start Cond. OK	Digital Status	Report by Exception	5 min poll
Electrolyzer - Cell Stack 2 Start Cond. OK	Digital Status	Report by Exception	5 min poll
Electrolyzer HWSS Alarm	Digital Status	Report by Exception	5 min poll
Electrolyzer Fire Detection Alarm	Digital Status	Report by Exception	5 min poll
Electrolyzer - Cell Stack 1 Status	Digital Status	Report by Exception	5 min poll
Electrolyzer - Cell Stack 2 Status	Digital Status	Report by Exception	5 min poll
52B1B3 Alarms			
52B1B3 Breaker BE1-700C Alarm / Trip	Digital Status	Report by Exception	5 min poll
52B1B3 Breaker BE1-700V Alarm / Trip	Digital Status	Report by Exception	5 min poll

APPENDIX B. MICROCONTROLLER (DAS) SOURCE CODE

```
char i;
char trash_;
int v = 0;

void main()
{
  USART_init(57600);                  // initialize USART module
                              // (8 bit, 57600 baud rate, no parity bit...)
  PORTB = 0;                          // Initialize PORTB
  TRISB = 1;                          // Configure PORTB as output
  v = 1;                            // validate send / receive data
  Delay (8000);                      //Delay of 8s to let XPORT initialize
  while (1)
  {
   if (v == 1)                      //Trying Tx through XPORT
   {
    PORTB = 12;                     //Enable XPORT / green light / Disable Wireless
    USART_Write("Wind speed: 10m/s");    //send data via USART
    Delay_ms (1) ;                 //delay of 1ms
    if (USART_Data_Ready())          // if data is received
    {
     i = USART_Read();               // read the received data
      if (i == 'x')              //acknowledgment Xport
      {
      v = 1;
      }
      else
      {
      v = 2;
      }
    }
    else
    {
     v = 2;
    }
   }}
   if (v == 2)                      //Trying Tx through wireless
   {
    PORTB = 18;                     //Enable Wireless / red light / Disable XPORT
//---------------Start Empty trash can
   if (USART_Data_Ready())            // if trash data is received
```

```
    {
      trash_ = USART_Read();          // read the received trash data
    }
  //---------------Finish Empty trash can
    USART_Write("Wind speed: 10m/s");  //send data via USART
    Delay_ms (1) ;                  //delay of 1ms
    if (USART_Data_Ready()          // if data is received
    {
     i = USART_Read();                // read the received data
      if (i == 'w')                  //acknowledgment Wireless
      {
        v = 1;
      }
      else
      {
        v = 3;
      }
     }}
    else
    {
     v = 3;
     }
    }
    if (v == 3)                      //Tx Failure
    {
     PORTB = 6;                        //Disable Wireless / Disable XPORT / No light
     v = 1;
    }
    Delay (6000);                     //delay of 6s
     }
  }
```

APPENDIX C. GRAPHIC USER INTERFACE SOURCE CODE

```
Option Explicit
Dim xport_rx As String
Dim wireless_rx As String
Dim m As String
Dim n As String
Dim temp As Integer
Dim numfile As Integer
Dim numfile2 As Integer
Dim LineaDeTexto As String
Dim TodoElTexto As String
Dim modu As String

Private Sub StopCommand_Click()
  Text1.Text = ""
  Text2.Text = ""
  If MSComm1.PortOpen = True Then
  '  MSComm1.PortOpen = False
  End If
  If MSComm3.PortOpen = True Then
  '  MSComm3.PortOpen = False
  End If
End Sub

Private Sub StartCommand_Click()
 ' m = "e"
  Text1.Text = ""
  Text2.Text = ""
  m = "ex"
  n = "ew"
  MSComm1.PortOpen = True
  MSComm3.PortOpen = True
  Do
    DoEvents
    If MSComm3.InBufferCount > 0 Then
      xport_rx = MSComm3.Input
      Text1.Text = Text1.Text + xport_rx
      xport_rx = "w"
      If m = "ex" Then
        MSComm3.Output = xport_rx
      End If
    '  numfile = numfile + 1
    '  Label2.Caption = "XPORT: " + numfile
    End If
    If MSComm1.InBufferCount > 0 Then
      wireless_rx = MSComm1.Input
```

```
         Text2.Text = Text2.Text + wireless_rx
         wireless_rx = "x"
         If n = "ew" Then
            MSComm1.Output = wireless_rx
         End If
        ' numfile2 = numfile2 + 1
        ' Label2.Caption = "Wireless: " + numfile2
      End If
   Loop Until m = "s"
   MSComm3.PortOpen = False
   MSComm1.PortOpen = False
End Sub

Private Sub ExitCommand_Click()
   m = "s"
   If MSComm1.PortOpen = True Then
      MSComm1.PortOpen = False
   End If
   If MSComm3.PortOpen = True Then
      MSComm3.PortOpen = False
   End If
End
End Sub

Private Sub DisablePLCCommand_Click()
   m = "dx" 'disable XPORT
End Sub

Private Sub DisableWCommand_Click()
   n = "dw" 'disable Wireless
End Sub

Private Sub EnablePLCCommand_Click()
   m = "ex" 'Enable XPORT
End Sub

Private Sub EnableWCommand_Click()
   n = "ew" 'Enable Wireless
End Sub

Private Sub Form_Load()
   MSComm1.InputLen = 1024
   MSComm3.InputLen = 1024
End Sub
```

APPENDIX D. COMPONENTS' DATASHEETS USED FOR THIS PROJECT

National
Semiconductor

February 2003

LM6171

High Speed Low Power Low Distortion Voltage Feedback Amplifier

General Description

The LM6171 is a high speed unity-gain stable voltage feedback amplifier. It offers a high slew rate of 3600V/µs and a unity-gain bandwidth of 100 MHz while consuming only 2.5 mA of supply current. The LM6171 has very impressive AC and DC performance which is a great benefit for high speed signal processing and video applications.

The ±15V power supplies allow for large signal swings and give greater dynamic range and signal-to-noise ratio. The LM6171 has high output current drive, low SFDR and THD, ideal for ADC/DAC systems. The LM6171 is specified for ±5V operation for portable applications.

The LM6171 is built on National's advanced VIP™ III (Vertically Integrated PNP) complementary bipolar process.

Features

(Typical Unless Otherwise Noted)

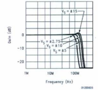
- Easy-To-Use Voltage Feedback Topology
- Very High Slew Rate: 3600V/µs
- Wide Unity-Gain-Bandwidth Product: 100 MHz
- −3dB Frequency @ $A_V = +2$: 62 MHz
- Low Supply Current: 2.5 mA
- High CMRR: 110 dB
- High Open Loop Gain: 90 dB
- Specified for ±15V and ±5V Operation

Applications

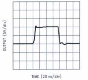
- Multimedia Broadcast Systems
- Line Drivers, Switchers
- Video Amplifiers
- NTSC, PAL® and SECAM Systems
- ADC/DAC Buffers
- HDTV Amplifiers
- Pulse Amplifiers and Peak Detectors
- Instrumentation Amplifier
- Active Filters

Typical Performance Characteristics

Closed Loop Frequency Responsevs. Supply Voltage
($A_V = +1$)



Large Signal Pulse Response
$A_V = +1$, $V_S = \pm15$



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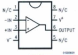
Connection Diagram

8-Pin DIP/SO



Top View

Ordering Information

Package	Temperature Range	Transport Media	NSC Drawing
	Industrial −40˚C to +85˚C		
8-Pin Molded DIP	LM6171AIN LM6171BIN	Rails	N08E
8-Pin Small Outline	LM6171AIM, LM6171BIM	Rails	M08A
	LM6171AIMX, LM6171BIMX	2.5k Units Tape and Reel	

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

ESD Tolerance (Note 2)	2.5 kV
Supply Voltage (V^+-V^-)	36V
Differential Input Voltage	±10V
Common-Mode Voltage Range	V^++0.3V to V^- −0.3V
Input Current	±10mA
Output Short Circuit to Ground (Note 3)	Continuous
Storage Temperature Range	−65°C to +150°C
Maximum Junction Temperature (Note 4)	150°C
Soldering Information	
Infrared or Convection Reflow (20 sec.)	235°C
Wave Soldering Lead Temp (10 sec.)	260°C

Operating Ratings (Note 1)

Supply Voltage	$5.5V \le V_S \le 34V$
Operating Temperature Range	
LM6171AI, LM6171BI	−40°C to +85°C
Thermal Resistance (θ_{JA})	
N Package, 8-Pin Molded DIP	108°C/W
M Package, 8-Pin Surface Mount	172°C/W

±15V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = +15V, V^- = −15V, V_{CM} = 0V, and R_L = 1 kΩ. **Boldface limits apply at the temperature extremes**

Symbol	Parameter	Conditions	Typ (Note 5)	LM6171AI Limit (Note 6)	LM6171BI Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		1.5	3 **5**	6 **8**	mV max
TC V_{OS}	Input Offset Voltage Average Drift		6			μV/°C
I_B	Input Bias Current		1	3 **4**	3 **4**	μA max
I_{OS}	Input Offset Current		0.03	2 **3**	2 **3**	μA max
R_{IN}	Input Resistance	Common Mode	40			MΩ
		Differential Mode	4.9			
R_O	Open Loop Output Resistance		14			Ω
CMRR	Common Mode Rejection Ratio	V_{CM} = ±10V	110	80 **75**	75 **70**	dB min
PSRR	Power Supply Rejection Ratio	V_S = ±15V to ±5V	95	85 **80**	80 **75**	dB min
V_{CM}	Input Common-Mode Voltage Range	CMRR ≥ 60 dB	±13.5			V
A_V	Large Signal Voltage Gain (Note 7)	R_L = 1 kΩ	90	80 **70**	80 **70**	dB min
		R_L = 100Ω	83	70 **60**	70 **60**	dB min
V_O	Output Swing	R_L = 1 kΩ	13.3	12.5 **12**	12.5 **12**	V min
			−13.3	−12.5 **−12**	−12.5 **−12**	V max
		R_L = 100Ω	11.6	9 **8.5**	9 **8.5**	V min
			−10.5	−9 **−8.5**	−9 **−8.5**	V max
	Continuous Output Current (Open Loop) (Note 8)	Sourcing, R_L = 100Ω	116	90 **85**	90 **85**	mA min

The fastest way to wireless.

High-performance AC4790 transceivers utilize AeroComm's "masterless" protocol, allowing each transceiver to communicate with any other in-range transceiver for true peer-to-peer operation.

Using field-proven 900MHz FHSS technology that needs no additional site licensing*, AC4790s reject interference, enable co-located system operation, increase output power and maintain data integrity.

AC4790's protocol features a dynamic addressing scheme, which simplifies node-to-node communication. The transceiver enables identification of the most efficient transmission path, so OEMs can design routing sequences that optimize the RF network. This makes AC4790 ideal for a wide variety of industrial applications that must rely on smooth, constant data flow.

Developer tools and integration support back every transceiver line. Let AeroComm help you find the best fit for your application.

AC4790 Highlights

- *True peer-to-peer protocol.*
- *Ultra-fast sync time (25 msec).*
- *Small form factor: 1.65 x 1.9 inches.*
- *API commands to control packet routing.*
- *Software-controlled sensitivity.*
- *Network node discovery.*
- *Variable output power: 5mW to 1000mW.*

Applications

Commercial Buildings
- Security & fire alarms
- Lighting controls
- Surveillance
- Building automation
- HVAC controls

Field Surveillance
- SCADA
- Oil & gas
- Water & wastewater
- Tank monitoring
- Activity alarms

Utilities Management
- Automatic meter reading
- Load profiling, forecasting
- Data management
- Tampering alerts
- Real-time support

Recreation Areas
- Golf cart tracking
- Score keeping
- Order entry
- Irrigation systems
- Grounds maintenance

Fleet Telemetry
- Vehicle tracking
- Cargo data
- Weigh scales
- Maintenance logs
- Mapping

Specifications

PARAMETER	AC4790–200	AC4790–1000
Interface	20-pin mini connector	20-pin mini connector
Frequency (software selectable)	902-928 MHz (U.S.)*	902-928 MHz (U.S.)*
Modulation	FHSS FSK	FHSS FSK
Serial interface options	3V or 5V TTL	3V TTL
Serial interface data rate	Up to 115.2 Kbps	Up to 115.2 Kbps
Output power (w/ 3dBi antenna)	5mW-200mW variable	5mW-1000mW variable
Power consumption†	68 mA typical	650 mA typical
Channels	Up to 48 (U.S.)**	Up to 32 (U.S.)**
Security	One-byte system ID, DES	One-byte system ID, DES
Voltage	3.3V-5.5V	pin 10: 3.3V-5.5V; pin 11: 3.3V +/-3%
Sensitivity (adjustable)	-110 dB in "long range" mode	-110 dB in "long range" mode
Range (line-of-sight)	Up to 4 miles (up to 6.5 km) with external antenna	Up to 20 miles (up to 32 km) with high-gain antenna
Temperature	-40° to +80°C	-40° to +80°C
Humidity (non-condensing)	10% to 90%	10% to 90%
Dimensions	1.90 x 1.65 x 0.20 inches (49 x 42 x 5 mm)	1.90 x 1.65 x 0.20 inches (49 x 42 x 5 mm)
Weight	< 0.75 oz (< 21 g)	< 0.75 oz (< 21 g)
Antenna	Integral or external dipole††	External dipole††

* The 900MHz frequency band is approved in the Americas and Australia as an unlicensed spectrum subject to approval by device.
**For products and specifications suited to non-U.S. countries, please contact AeroComm directly.
† Power consumption assumes 50% transmitter on-time.
†† Higher-gain antennas optional.

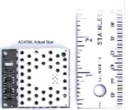
AEROCOMM

11160 Thompson Avenue · Lenexa, Kansas 66219 | Phone 913.492.2320 | Fax 913.492.1243 · Web www.aerocomm.com

Flexible RF Protocol

AeroComm's RF232™ embedded transparent protocol simplifies the OEM's integration process by allowing for drop-in installation. As each transceiver receives raw data, it manages over-the-air protocol to assure successful communication. Headers, data packet length, and CRCs are not needed.

AC4790's flexible "masterless" topology supports simple cable-replacement up to complex peer-to-peer configurations. Broadcast communication to all transceivers or address packets to a specific destination using unique MAC addresses embedded in each transceiver.



AC4790, Actual Size

Protocol Features

RF PROTOCOL MODES

a) **Communication**
   Unicast (one-to-one addressing)
   Broadcast (one-to-many addressing)

b) **Acknowledgement mode (ACK)**
   API with hardware and/or software ACK indication

c) **Ultra-fast sync time**
   Up to 25 simultaneous conversations
   Intelligent self-extending session time requires only one 25 msec sync

d) **Remote over-the-air configuration**

e) **Sensadjust**
   Software-controlled RF desensitizer wards off interference

f) **Random back-off**

g) **Network node discovery**

h) **Dynamic radio data table**
   Retains data from up to 8 transceivers

INTERFACE PROTOCOL

a) **On-the-fly transceiver configuration**
   Full API Control
   Destination address
   RF transmit power
   RF Channel
   Broadcast/addressed

b) **Raw data or transmit/receive API**

c) **Long range mode**
   Enables sensitivity control

d) **A/D, D/A generic I/Os**

e) **Variable baud rate**

f) **RF packet size, timeout control**

g) **Onboard temperature sensor**

h) **Handshaking**
   CTS/RTS

i) **In-range indicator**

j) **Error detection**
   Onboard CRC
   Duplicate packet filtering

k) **Data encryption standard (DES)**

ARCHITECTURE

Peer-to-peer

Placing Orders

Select features from the list below to identify the appropriate part number. More product lines are available for industrial & commercial applications. Contact AeroComm Sales for details: toll-free 1-800-492-2320, email sales@aerocomm.com.

PART NUMBERS

AC4790-200M
900MHz transceiver, 3.3V-5.5V, TTL serial, 0–10mW, -40° to +80° C, MMCX antenna

AC4790-200A
900MHz transceiver, 3.3V-5.5V, TTL serial, 0–10mW, -40° to +80° C, integral antenna

AC4790-1000M
900MHz transceiver, 3.3V, TTL serial, 5–1000mW, -40° to +80° C, MMCX antenna

AC4790-1x1
See AC4790-1x1 datasheet.

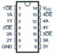
AEROCOMM

SN54ABT125, SN74ABT125
QUADRUPLE BUS BUFFER GATES
WITH 3-STATE OUTPUTS

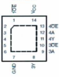
SCBS182I – FEBRUARY 1997 – REVISED NOVEMBER 2002

- Typical V_{OLP} (Output Ground Bounce) <1 V at V_{CC} = 5 V, T_A = 25°C
- High-Drive Outputs (–32-mA I_{OH}, 64-mA I_{OL})
- I_{off} and Power-Up 3-State Support Hot Insertion
- Latch-Up Performance Exceeds 500 mA Per JEDEC Standard JESD-17
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 200-V Machine Model (A115-A)

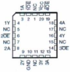
SN54ABT125 . . . J OR W PACKAGE
SN74ABT125 . . . D, DB, N, NS, OR PW PACKAGE
(TOP VIEW)



SN74ABT125 . . . RGY PACKAGE
(TOP VIEW)



SN54ABT125 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

The 'ABT125 quadruple bus buffer gates feature independent line drivers with 3-state outputs. Each output is disabled when the associated output-enable ($\overline{OE}$) input is high.

These devices are fully specified for hot-insertion applications using I_{off} and power-up 3-state. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the devices when they are powered down. The power-up 3-state circuitry places the outputs in the high-impedance state during power up and power down, which prevents driver conflict.

To ensure the high-impedance state during power up or power down, $\overline{OE}$ should be tied to V_{CC} through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	PDIP – N	Tube	SN74ABT125N	SN74ABT125N
	QFN – RGY	Tape and reel	SN74ABT125RGYR	AB125
	SOIC – D	Tube	SN74ABT125D	ABT125
		Tape and reel	SN74ABT125DR	
	SOP – NS	Tape and reel	SN74ABT125NSR	ABT125
	SSOP – DB	Tape and reel	SN74ABT125DBR	AB125
	TSSOP – PW	Tape and reel	SN74ABT125PWR	AB125
–55°C to 125°C	CDIP – J	Tube	SNJ54ABT125J	SNJ54ABT125J
	CFP – W	Tube	SNJ54ABT125W	SNJ54ABT125W
	LCCC – FK	Tube	SNJ54ABT125FK	SNJ54ABT125FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

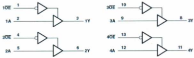
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

FUNCTION TABLE
(each buffer)

INPUTS		OUTPUT
$\overline{OE}$	A	Y
L	H	H
L	L	L
H	X	Z

logic diagram (positive logic)



Pin numbers shown are for the D, DB, J, N, NS, PW, RGY, and W packages.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC}	–0.5 V to 7 V
Input voltage range, V_I (see Note 1)	–0.5 V to 7 V
Voltage range applied to any output in the high or power-off state, V_O	–0.5 V to 5.5 V
Current into any output in the low state, I_O: SN54ABT125	96 mA
SN74ABT125	128 mA
Input clamp current, I_{IK} ($V_I < 0$)	–18 mA
Output clamp current, I_{OK} ($V_O < 0$)	–50 mA
Package thermal impedance, θ_{JA} (see Note 2): D package	86°C/W
(see Note 2): DB package	96°C/W
(see Note 2): N package	80°C/W
(see Note 2): NS package	76°C/W
(see Note 2): PW package	113°C/W
(see Note 3): RGY package	47°C/W
Storage temperature range, T_{stg}	–65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. The input and output negative-voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
2. The package thermal impedance is calculated in accordance with JESD 51-7.
3. The package thermal impedance is calculated in accordance with JESD 51-5.

LANTRONIX®

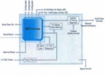
XPort™ Data Sheet

General Description

The XPort™ is the most compact, integrated solution available to web-enable any device with a serial interface. By simply adding XPort™ to a product design, device manufacturers cut their design cycle by as much as 80% and are able to offer Ethernet connectivity in record time.

The XPort offers the highest level of integration available in a device server. Within a compact RJ45 package is a DSTni-EX 186 controller, memory, 10/100 Ethernet transceiver, high-speed serial port, status/diagnostic LEDs, and 3 programmable I/O pins. In the space that is normally consumed by a connector, the XPort provides a complete networking interface.

To enable access to a local network or the Internet, the XPort integrates a fully developed TCP/IP network stack and OS. The XPort also includes an embedded web server used to remotely configure, monitor, or troubleshoot the attached device.



Where there's a need for custom user interfaces and a desire to use common and familiar tools, the XPort can serve web pages to a web browser. The XPort becomes a conduit between you and your device over the network or Internet.

The Windows™-based configuration software, DeviceInstaller, simplifies installation and setup. The XPort can also be set up locally through its serial port, or remotely over a network using Telnet or a web browser. Flash memory provides for maintenance-free nonvolatile storage of web pages, and allows future system software upgrades.

Using our highly integrated hardware and software platform, you will add profit to your bottom line by significantly reducing product development time, risk, and cost.

Key Features

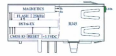
- The only complete, integrated solution in an RJ45 form factor
- Complete integrated solution
- Embedded web server
- 10/100Mbit Ethernet – Auto-Sensing
- Stable, field proven TCP/IP protocol suite and web-based application framework
- Easy configuration through a web interface
- Easy customization of HTML web pages and configuration screens
- Interactive web pages through the use of Java applets
- E-mail
- 128-, 192-, or 256-bit AES Rijndael encryption (Optional)
- EMI tested and compliant
- Extended operating temperature:
  -40 to +85° C normal mode
  -40 to +75° C high-performance mode
- High-performance processor
  (12 MIPS at 48 MHz, 22 MIPS at 88 MHz)
- Network overhead handled by XPort
- Password protection
- Upgrade XPort's firmware over the network
- 3.3V power
- Serial-to-10/100 Ethernet conversion
- 921,600 baud serial speed

Hardware & Software Description

The XPort is a complete solution (hardware and software) for web-enabling your edge devices. Packed into an RJ45 connector smaller than your thumb, this powerful device server comes with a 10BASE-T/100BASE-TX Ethernet connection, a reliable and proven operating system stored in flash memory, an embedded web server, a full TCP/IP protocol stack, and standards-based (AES) encryption.

The XPort software runs on a DSTni-EX controller which has 256 KB of SRAM, 16 KB of boot ROM, and a MAC with integrated 10/100BASE-TX PHY. The XPort communicates to the edge device through a 3.3V serial interface and three general-purpose programmable I/O pins. 512 KB of flash memory is included for storing firmware and web pages. The XPort runs on 3.3V, and has a built-in voltage supervisory circuit that will trigger a reset if the supply voltage drops to unreliable levels (2.7V). A built-in 1.8V regulator drives the processing core of the EX controller.

An RJ45 Ethernet cable connects directly into an XPort. Ethernet magnetics, status LEDs, and shielding are built in. The XPort was designed to meet class B emissions levels, which makes the electromechanical integration very simple.



PCB Interface

The 8-pin PCB interface consists of 3.3V CMOS Serial In/Out, 3 Flow Control/Handshake/PIO pins, reset input, +3.3V power, and signal ground. Signal pins Data In, Data Out and CPx are 5V tolerant.

Table 1 - PCB Interface Signals

Signal Name	Pin	Function
GND	1	Circuit Ground
Vcc	2	+3.3V Power In
Reset (In)	3	External Reset In
Data OUT	4	Serial Data Out
Data IN	5	Serial Data In
CP0	6	CP1 can be configured as follows: • **Flow control**: RTS (Request to Send) **output** driven by DSTni's **built-in** UART for connection to CTS of attached device. • **Programmable input/output**: CP1 can be driven or read through software control, independent of serial port activity.
CP1	7	CP2 can be configured as follows: • **Modem control**: DTR (Data Terminal Ready) **output** driven by DSTni's built-in UART for connection to DCD of attached device. • **Programmable input/output**: CP2 can be driven or read through software control, independent of serial port activity.
CP2	8	CP3 can be configured as follows: • **Flow control**: CTS (Clear to Send) **input** read by DSTni's built-in UART for connection to RTS of attached device. • **Modem control**: DCD (Data Carrier Detect) **input** read by DSTni's built-in UART for connection to DTR of attached device. • **Programmable input/output**: CP3 can be driven or read through software control, independent of serial port activity.

Ethernet Interface

The 10/100 Ethernet magnetics, network status LEDs, and RJ45 connector are integrated into the XPort.

Table 2 - Ethernet Interface Signals

Signal Name	DIR	Contact	Primary Function
TX+	Out	1	Transmit Data +
TX-	Out	2	Transmit Data –
RX+	In	3	Receive Data +
RX-	In	6	Receive Data –
Not Used		4	Terminated
Not Used		5	Terminated
Not Used		7	Terminated
Not Used		8	Terminated
SHIELD			Chassis Ground

Protocol Support

The XPort uses Internet Protocol (IP) for network communications and Transmission Control Protocol (TCP) to assure that no data is lost or duplicated, and that everything sent arrives correctly at the target.

Other supported protocols are listed below:

- ARP, UDP, TCP, ICMP, Telnet, TFTP, AutoIP, DHCP, HTTP, and SNMP for network communications.
- TCP, UDP, and Telnet for connections to the serial port.
- TFTP for firmware updates.
- IP for addressing, routing, and data block handling over the network.
- User Datagram Protocol (UDP) for typical datagram applications in which devices interact with other devices without maintaining a point-to-point connection.

* For a complete discussion of protocol support, see the XPort user manual.

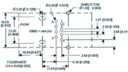
LEDs

The device contains two bi-color LEDs built into the front of the XPort connector. (See dimension drawing for location.)

Link LED (Left Side)		Activity LED (Right Side)	
Color	Meaning	Color	Meaning
Off	No Link	Off	No Activity
Amber	10 Mbps	Amber	Half-Duplex
Green	100 Mbps	Green	Full-Duplex

Recommended PC Board Layout

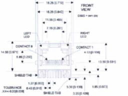
The hole pattern and mounting dimensions for the XPort are shown in the following drawing:



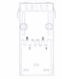
For proper heat dissipation, the PCB should have approximately 1 square inch of copper attached to the shield tabs. The shield tabs are an important source of heat sinking for the device.

Dimensions

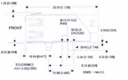
The XPort dimensions are shown in the following drawings:



Bottom View



Side View

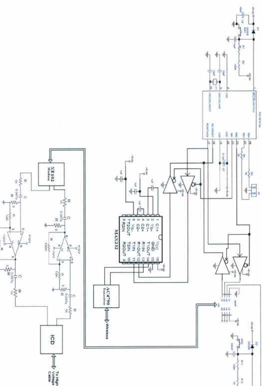


Note: PADS and PROTEL design files are included with the XPort development kit.

XPort Technical Data

Category	Description
CPU, Memory	Lantronix DSTni-EX 186 CPU, 256 KB zero wait state SRAM 512 KB Flash, 16 KB Boot ROM
Firmware	Upgradeable via TFTP and serial port
Reset Circuit	Internal 200ms power-up reset pulse. Power-drop reset triggered at 2.6V. External reset input causes an internal 200ms reset.
Serial Interface	CMOS (Asynchronous) 3.3V-level signals Rate is software selectable (300 bps to 921600 bps)
Serial Line Formats	7 or 8 data bits, 1-2 Stop bits, Parity: odd, even, none
Modem Control	DTR/DCD, CTS, RTS
Flow Control	XON/XOFF (software), CTS/RTS (hardware), none
Programmable I/O	3 PIO pins (software selectable) sink or source 4mA max.
Network Interface	RJ45 Ethernet 10BASE-T or 100BASE-TX (auto-sensing)
Compatibility	Ethernet: Version 2.0/IEEE 802.3
Protocols Supported	ARP, UDP/IP, TCP/IP, Telnet, ICMP, SNMP, DHCP, BOOTP, TFTP, Auto IP, and HTTP
LEDs	10BASE-T & 100BASE-TX Link Activity, Full/half duplex. Sofware generated status & diagnostic signals can optionally drive external LEDs through CP1 & CP3 (see Int. Guide).
Management	Internal web server, SNMP, Serial login, Telnet login
Security	Password protection, locking features, optional Rijndael 128-, 192-, or 256-bit encryption
Internal Web Server	Serves web pages Storage capacity: 384 KB
Weight	9.6 grams (0.34 oz)
Material	Metal shell, thermoplastic case
Temperature	Operating range: Commercial Temp RoHS product: 0°C to +70°C (32°F to 158°F) Extended Temp RoHS product: -40°C to +85°C (-40°F to 185°F) Storage range: -40°C to +85°C (-40°F to 185°F)
Relative Humidity	Operating: 5% to 95% non-condensing
Shock/Vibration	Non-operational shock: 500 g's, Non-operational vibration: 20 g's
Warranty	2-year limited warranty
Included Software	Windows™ 98/NT/2000/XP-based DeviceInstaller configuration software and Windows™-based Comm Port Redirector
EMI Compliance	Radiated & conducted emissions - complies with Class B limits of EN 55022:1998 Direct & Indirect ESD - complies with EN55024:1998 RF Electromagnetic Field Immunity - complies with EN55024:1998 Electrical Fast Transient/Burst Immunity - complies with EN55024:1998 Power Frequency Magnetic Field Immunity - complies with EN55024:1998 RF Common Mode Conducted Susceptibility - complies with EN55024:1998

APPENDIX E. DATA ACQUISITION SYSTEM TRANSMITTER SCHEMATIC


PIC18F452A
MAX232
1 C1+
2 VS+
3 C1-
4 C2+
5 C2-
6 VS-
7 T2OUT
8 R2IN
16 Vcc
15 GND
14 T1OUT
13 R1IN
12 R1OUT
11 T1IN
10 T2IN
9 R2OUT
AC4790
Transceiver
Wireless
XE102
Modem
ICD
To High Voltage Cable
D1
D2
R1
R2
R3
R4
R11
R12
C1
C2
C3
J1
J2