ENERGY EFFICIENCY AND CONSERVATION BLOCK GRANT (EECBG) - BETTER BUILDINGS NEIGHBORHOOD PROGRAM

FINAL REPORT

Missouri Agricultural Energy Saving Team-A Revolutionary Opportunity (MAESTRO)

DISCLAIMER

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Notice

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Report Title

2. Title Cover Page:

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Missouri Agricultural Energy Saving Team-A Revolutionary Opportunity (MAESTRO)

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Missouri Department of Agriculture; University of Missouri; Missouri Agricultural and Small Business Development Authority; EnSave, Inc.

Executive Summary

3. Project Summary:

The Missouri Agricultural Energy Saving Team-A Revolutionary Opportunity (MAESTRO) program brought together a team of representatives from government, academia, and private industry to enhance the availability of energy efficiency services for small livestock producers in the State of Missouri. The Missouri Department of Agriculture (MDA) managed the project via a subcontract with the University of Missouri (MU), College of Agriculture Food and Natural Resources, MU Extension, the MU College of Human Environmental Sciences, the MU College of Engineering, and the Missouri Agricultural and Small Business Development Authority (MASBDA). MU teamed with EnSave, Inc, a nationally-recognized expert in agricultural energy efficiency to assist with marketing, outreach, provision of farm energy audits and customer service. MU also teamed with independent home contractors to facilitate energy audits of the farm buildings and homes of these livestock producers.

The goals of the project were to: (1) improve the environment by reducing fossil fuel emissions and reducing the total energy used on small animal farms; (2) stimulate the economy of local and regional communities by creating or retaining jobs; and (3) improve the profitability of Missouri livestock producers by reducing their energy expenditures.

Historically, Missouri scientists/engineers conducted programs on energy use in agriculture, such as in equipment, grain handling and tillage practices. The MAESTRO program was the first to focus strictly on energy efficiency associated with livestock production systems in Missouri and to investigate the applicability and potential of addressing energy efficiency in animal production from a building efficiency perspective.

A. Project Objectives

The goal of the MAESTRO program was to strengthen the financial viability and environmental soundness of Missouri's small animal farms by helping them implement energy efficient technologies for the production facility, farm buildings, and the homes on these farms.

The expected measurable outcomes of the project were to improve the environment and stimulate the economy by:

- Reducing annual fossil fuel emissions by 1,942 metric tons of carbon dioxide equivalent, reducing the total annual energy use on at least 323 small animal farms and 100 farm homes by at least 8,000 kWh and 2,343 therms per farm.
- Stimulating the economy by creating or retaining at least 69 jobs, and saving small animal farmers an average of $2,071 per farm in annual energy expenditures.

B. Project Scope

The MAESTRO team chose the target population of small farms because while all agriculture is traditionally underserved in energy efficiency programs, small farms were particularly underserved because they lack the financial resources and access to energy efficiency technologies that larger farms deploy. The MAESTRO team reasoned that energy conservation, financial and educational programs developed while serving the agricultural community could serve as a national model for other states and their agricultural sectors.

The target population was approximately 2,365 small animal farm operations in Missouri, specifically those farms that were not by definition a confined animal feeding operation (CAFO).

The program was designed to create jobs by training Missouri contractors and Missouri University Extension staff how to conduct farm audits. The local economy would be stimulated by an increase in construction activity and an increasing demand for energy efficient farm equipment. Additionally, the energy savings were deemed critical in keeping Missouri farms in business.

This project leveraged funds using a combination of funds from the Missouri Department of Natural Resources' Missouri Energy Center and its Soil and Water Conservation Program, from the state's Linked Deposits, MASBDA's agricultural loan guarantee programs, and through the in-kind contribution of faculty and staff time to the project from these agencies and MU. Several hundred Missouri livestock producers were contacted during the MAESTRO project. Of the livestock producers, 254 invited the team to conduct a farm energy assessment which complied with ASABE 612. A total of 147 livestock farm upgrades were implemented, representing 57.5 percent of the farms for which a farm energy assessment was completed. This represented a statewide average annual savings of 1,088,324 kWh and 75,516 therms.

The team also reviewed the condition of the livestock producer's home(s). A total of 106 home energy assessments were completed and 48 individual homes implemented their recommended upgrades, representing 45 percent of the farm homes for which an energy assessment was completed. This represented a statewide average annual savings of 323,029 kWh, and 769.4 therms. More of these farmers likely would have updated their homes but the funding to incentivize them fell short. In spite of the shortfall in incentive funds, some farmers still updated their homes as they saw the value in making these changes to their home.

Final Technical Report - Farm

4. Farm Energy Pillars:

A. Institutional Design and Business Model

The goal of this project was to strengthen the financial viability and environmental soundness of Missouri's small animal farms by helping them become national leaders in the use of energy efficient technologies. To do this, a collaborative project team led by the Missouri Department of Agriculture, the University of Missouri, and EnSave, Inc. worked to saturate the small animal farm sector in Missouri with energy efficiency education and retrofits. One of our initial goals was to establish and make use of a revolving loan fund to contract and facilitate retrofitting.

The Missouri Department of Agriculture (MDA), in pursuit of its mission statement "To serve, promote, and protect the agricultural producers, processors, and consumers of Missouri's food, fuel, and fiber products", and understanding the benefits to its farmer-clients of improved energy efficiency in their operations sought and obtained this BBNP grant and then managed the funds and overall work of the project. MDA employed the assistance of the Missouri Agricultural and Small Business

Development Authority (MASBDA), a state agency that reviews and approves loan applications for the authority's programs. MASBDA managed the grant awards and loans needed to incentivize the purchase of energy savings technology by the farmers.

The Curators of the University of Missouri (MU) managed the day to day activities of the MAESTRO program. The overall coordinator of the program for MU was the faculty of College of Agriculture, Food, and Natural Resources (CAFNR). CAFNR faculty coordinated the work of several groups: MU Extension faculty who provided information to farmers, assisted with farm audits, auditor training, and verified farm retrofits; College of Engineering (COE) faculty who designed and implemented evaluation, measurement, and verification (EM&V) activities; and, Human Environmental Sciences (HES) faculty who secured home auditors, and verified the home retrofits. CAFNR faculty also coordinated the marketing efforts, farm audit training, and farm audits conducted by EnSave, Inc. EnSave, Inc. had conducted similar efforts in other states and EnSave teamed up with CAFNR faculty to essentially jump start the effort.

We felt MAESTRO could serve as a national model to facilitate the adoption of energy conservation equipment on small livestock farms, a model that would result in adoption of new energy saving technologies. These efforts would result in significant energy usage reductions and ultimately improve the financial bottom line of these small farms- keeping small animal farmers in operation and in their homes.

B. Program Design and Customer Experience

The plan was to focus on the population of small animal farms in Missouri, specifically those farms in the swine, poultry and dairy industries that by definition were not required to be permitted by the Missouri Department of Natural Resources (DNR) as a Confined Animal Feeding Operation (CAFO). We planned to approach these farms for farm energy audits and then work with them to apply for loans to improve the energy efficiency of their farm operation or farm house. EnSave offered farm energy audits provided by its engineering staff, with on-site data collection performed by Missouri energy data collectors who were trained as part of the program. EnSave leased its Farm Energy Audit Tool (FEAT) to the University to aid staff in completing its own energy audits with EnSave's template and calculations. EnSave also provided farm "Technical Assistance" reports, which provided a simplified analysis of energy efficiency opportunities for farms that only wanted an analysis of one or two technologies rather than the entire farm. Home energy audits were provided by Missouri energy auditor subcontractors, certified by the Building Performance Institute and registered on the Missouri Department of Natural Resources' web page.

Our outreach plan was to engage the University of Missouri Extension field specialists to visit the farms to inform them of the program, and also use typical Extension avenues such as field days, fairs, and symposia to engage directly with farm managers. The Extension network runs deep in the state of Missouri, with Extension specialists living and working in every county of the state. It made sense to utilize this existing network to spread information about the program.

Simultaneous to the University's efforts, EnSave's service center reached out via phone to engage the farmers in the program, ultimately reaching over 5,000 farmers. EnSave capitalized on its network of agricultural organizations to help spread program information, and engaged national partners

(Innovation Center for U.S. Dairy, National Association of Resource Conservation & Development Councils, National Association of Conservation Districts) to help inform farmers of the program.

MASBDA also reached out to their network of Missouri lenders, borrowers, commodity associations, and agribusinesses via informational mailings, trade shows, and in-person contacts.

The program's outreach philosophy was a hands-on, more direct approach to farmers through phone calls and personal visits allowing success in engaging small livestock producers and informing them of the program's offerings.

C. Driving Demand

The MAESTRO team understood the grave need for projects that could reduce the small livestock producer's energy input costs. The number of small farmers (non-CAFO) in Missouri has declined each year. This project represented the potential for a significant impact on Missouri's economy - to keep these producers doing what they do best, and allow them to remain on the farm. This was the reason why the project focused its efforts on non-CAFO animal operations with more than $50,000 in farm revenues per year. The MAESTO team reasoned that these were the farmers with the greatest need for assistance assuming the financial burden of a retrofitting project.

The MAESTRO program offered several compelling reasons why Missouri livestock producers should adopt energy saving technology to save energy and improve their bottom line. These farmers immediately sensed a return on their investment (ROI). This as well as the encouragement of MU Extension personnel (and others) resulted in farmers making a call to EnSave so an informal energy assessment was conducted of their farm. The assessment often revealed a 15% energy savings and a ROI for the farmer. A financial incentive program was crafted to facilitate the purchase and install the energy saving technology for farm operations and residences.

MU Extension was key when reaching out to farmers. The extension personnel live and work in the local community - their voice is one that is trusted, along with the trusted voice of the MDA. MDA has provided financial assistance for years, and at times was likely the only reason a local farmer was able to keep farming.

The MU news service featured news articles about the MAESTRO program; placing a promotional video on YouTube. For example, a video like the following caught the eye of the farmer and helped foster a program following. (i.e. "MAESTRO program turns keen eye to energy usage on farms to trim costs." http://extension.missouri.edu/news/DisplayStory.aspx?N=1239).

MU and EnSave provided coordinated information campaigns that sent program announcements through the mail and email, and also made personal visits to farmers, agricultural and energy equipment vendors, and agricultural agencies and organizations to spread the word about MAESTRO.

The MAESTRO team personnel made presentations and staffed booths at a variety of county and state level fairs, field days and group meetings throughout the program period so that clients could have face-to-face conversations and explanations regarding program structure and opportunities. Personnel also provided information to clarify the opportunities available through MAESTRO and clear up confusion between it and other state and federal energy programs.

D. Workforce Development

The MAESTRO program expected that a minimum of 69 new permanent jobs would be created within the target population and that farmers would be able to remain gainfully employed on their own farm. We also expected that these producers would be reducing their carbon footprint by using less energy each year.

The MAESTRO program trained 21 new energy data collectors to conduct farm energy assessments and to support EnSave's audits. We helped sustain the businesses of 16 home energy auditors working throughout the state of Missouri.

We did not train any new "home" auditors, but we did put 16 home auditors to work. Due to the fact that REAP and other programs require that an energy assessment be done prior to making an application to/for other USDA sponsored programs, we believe they are still conducting audits.

E. Financing and Incentives

MASBDA initially set out to manage a revolving loan program to make the retrofits affordable for farmers. A total of $5,375,000 of the $10,000,000 initially requested was deemed necessary to incentivize the project. The initial proposal laid aside approximately $1,075,000 of the grant funds for loans to farmers who implemented the recommendations set forth in their audit. The balance of the funds were to be available for implementing energy savings retrofits ($4,300,000) as a revolving loan fund for the farmers who retrofitted with energy saving equipment and/or materials.

The loan payback period was structured to generally match the likely payback length of the retrofitting activities. MAESTRO recognized that the ability of farmers to pay back their loans was dependent on the increased revenue generated by energy savings. However, the bottom line of most small animal farmers did not provide room for additional loan payments. A payback period of 2 ½ years per loan was considered ideal. Adjustments were to be made based on the scope of the retrofitting activities.

Beginning with year four (post grant period), after all DOE grant funds had been expended, the program was to be sustained through a revolving loan fund—making it possible for a long-term impact on more animal farm operations, as well as other high energy use agricultural operations such as irrigation farmers or farmers who do extensive crop drying. Repayment of the loans was to be deposited into a revolving fund. Each year, new loans were to be distributed based on the previous year's ending balance and after personal services and expenses.

MASBDA is housed within the MDA and works extensively with Missouri farmers by helping new and expanding agricultural producers finance their operations and add value to their products through loan, grant and tax credit programs. MASBDA entered into a Memorandum of Agreement with the Missouri Department of Agriculture (MDA) in June 2010 and joined the MAESTRO program to develop and implement the program's financial incentives and funding structure component.

MASBDA prepared individual audit payments, audit rebates, implementation grants, interest down payments, cash down payments, and loan loss reserve documents as appropriate. MASBDA also assisted MU Extension in verifying completed projects for both farm operations and farm residence projects. MASBDA received and reviewed invoices and associated documentation submitted by funding recipients to MU Extension that supported recipients' requests for payments. Upon approval of recipients' requests for funds, MASBDA performed data tracking of the number of applications for funding received, the dollar amount of audit payments, audit rebates, implementation grants, interest buy downs, cash down payments, and guarantees paid from the loan loss reserve.

MASBDA submitted reports to MDA which included activities, performance metrics, and financial information required by the U.S. Department of Energy.

In the beginning of the program, the original financial incentives consisted of the following:

- Energy audits for the farm would cost $500 (value of $1,500) and the farm residence audits at a cost of $250 (value of $500).
- Rebate of energy audit cost when recommended equipment was installed
- Interest rate buy-down to 3% or equivalent amount as a cash down payment
- 75% loan guarantee for the banks
- Loans were not to exceed $10,000 (farms) and $15,000 (farm residence). Grants were not to exceed $2,000 (farms) and $3,000 (farm residence).

Early in the program, the MAESTRO team discovered that the farmers had very little interest in taking out a loan to make energy efficiency improvements on the farm. In addition, the up-front cost of the audit was too high for many farmers. Minimal participation in the program resulted. The MAESTRO team developed a new plan to encourage more participation. The funds that were initially set aside for the revolving loan fund were made available as grants to farmers. This reduced the farmer's up-front investment for both the farm and home audits. At the close of the project, the MAESTRO team had developed a solid incentive plan that increased participation:

- Farm Technical Assistance reports were provided at no cost to the farmer, to serve those with an interest in only one or two technologies
- Home retrofit grants available for 90% of project cost, not to exceed $8,000
- Farm retrofit grants available at 75% for project cost, not to exceed $12,000
- Farms that saved at least 10,000 kWh were eligible for 90% cost-share up to $20,000
- MASBDA offered to provide 25%-40% of project funding up front. This was done on an as-needed basis and designed to enable projects to move forward if a producer could not secure the total amount due to the contractor.

A complete month by month review of how the MAESTRO team developed and finally arrived at the final cost incentive program can be found in Appendix A. (The documents contained in Appendix A are the MAESTRO Process and the MAESTRO Timeline).

F. Data and Evaluation

EnSave, Inc. developed the initial Evaluation, Monitoring and Verification (EM&V) plan to investigate the energy efficiency of agriculture facilities in the State of Missouri. MU engineers refined/developed their own EM&V plan that was followed throughout the program. The EM&V program was designed to evaluate and verify energy savings within the program. A wireless EM&V system was developed, tested and established for remotely monitoring energy usage over a period of time. A greenhouse, poultry farm, two dairy farms, and a swine farm were monitored with this equipment. MU Engineers trained EM&V interns to carry out the bulk of the EM&V activities. At the close of their efforts they developed a 120 page detailed summary of their efforts. This information can be found in Appendix B.

Accomplishments –Farm

5. Comparing accomplishments with the goals and objectives of the project:

Marketing & Awareness

The marketing plan was designed to lessen the hesitancy of farmers to participate in the program. We began by contacting the local equipment dealers, manufacturers, and extended agricultural community (i.e. Farm Bureau, milk co-ops, commodity organizations, etc). Educating these entities about the program offerings became an additional marketing avenue and at the same time developed a sense of trust from the farmers. EnSave, Inc. contacted several of their national partnerships to leverage the Missouri representatives of these organizations: Dairy Farmers of America, the National Association of Resource Conservation and Development Councils, the Innovation Center for U.S. Dairy, and the National Association of Conservation Districts.

The MAESTRO team developed and distributed the following marketing/branding elements for the program: a logo, a one page flyer with program summary and benefits explained: revised through the several iterations of the program, a magnet advertising the program, a tri-fold brochure, PowerPoint presentations, posters, press releases, program posters for use at booth presentations, a survey to assess post-implementation feedback, a best practices guide designed to inform producers about common conservation and energy efficiency actions to be taken on the farm, case studies and technology information sheets designed to educate producers about specific technologies on the farm (brood curtains, compressor heat recovery units, milk pump variable speed drive, milk pre-cooler, scroll compressor, stock waterer, vacuum pump variable speed drive). These one page information sheets are located in Appendix C.

The MAESTRO team secured and hosted a website (www.moagenergysavings.com). This was used to attract farmers to the program, explain how they could be involved, and how they could contact MAESTRO. MU Extension activities and publications were targeted to sectors of the agricultural community. MAESTRO was featured in the following publications: *Associated Electric Cooperative, Inc., Rural Missouri, Joplin Stockyard, MO Ag Newspaper, Missouri Farmer Today, and the Missouri Dairy Association.* It can now be accessed through the MEERC (Midwest Energy Efficiency Research Consortium) web page: http://engineering.missouri.edu/research/centers/meerc/.

The team reached out to organizations that subsequently featured program information in their communications: The Poultry Yearbook, Missouri Livestock Market Directory, MFA Inc, equipment dealers and manufacturers such as John Deere, Case-IH, and AGCO. We also contacted Missouri organizations including the Missouri Rural Electric Coops, Young Farmers/Young Farmer Wives, Poultry Federation, the MU Ag Electronic Bulletin Board, the Missouri Farm Bureau, Missouri Cattleman, My Bliss Marketing, Missouri Soybean Association, Missouri Corn Growers, and more. Lighting related companies such as Halco Lighting, Next Gen Illuminations, Inc., and Once Innovations, Inc. also provided information about MAESTRO to Missouri Farmers.

EnSave hosted an energy efficiency workshop for Hmong farmers in the Southwest corner of the state. The workshop was designed to educate a historically underserved community of farmers about energy efficient opportunities and resources to obtain funding to implement energy efficient equipment. Guest speakers were Rebecca MacLeod, the National Energy Efficiency Liaison for United States Department of Agriculture/Natural Resources Conservation Services (NRCS), James Combs from United States Department of Agriculture Rural Development, and Tony Stafford from Missouri Agriculture & Small Business Development Authority. They presented financial opportunity information for the producers. There were also guests from the University of Missouri Extension, five local NRCS representatives, and two representatives from Tyson. This workshop resulted in 10 farm energy audits for these farms.

Summary of Farm Audit/Best Management Practices Numbers

MAESTRO contacted over 700 of the 2365 non-CAFO farms in Missouri (2010, 30% of the population), to conduct an energy audit via standard practices established by the American Society of Agricultural and Biological Engineers (ASABE). This practice was formally established by ASABE just prior to the start of MAESTRO. The table that follows provides a summary of the farms that remained with the program and adopted new energy efficient technologies:

Number of Farmer Participants	Upgrades Implemented for a 15% Energy Savings	Total Estimated Annual kWh Savings	Total Estimated Annual Therms Savings	Yearly kWh Savings in Dollars (7.8 cents)	Yearly Energy Therms Savings in Dollars
254	147	1,088,324	75,516	$84,889	$162,984

A therm is the equivalent of 100,000 BTU. As an example, one gallon of diesel fuel is 1.39 therms and diesel fuel was approximately $3.00 at the time of the study. The dollars saved as a result of the energy savings per farm was computed by adding $84,889 to $162,984 and then dividing by 147 retrofits. This equates to an annual energy savings of approximately $1,686 per farm. The annual savings per home (N=48, 7.8 cents/ kWh, 6,730 kWh) for electrical was $524.94. The total annual therms savings was $251.40 / home thus an average annual saving for each home was approximately $776.34.

One of the goals of the project was to reduce the annual energy costs for each farmer by $2,071. At first glance one wants to take the energy savings ($) from the home and simply add them to the energy savings ($) from the farm buildings and compare program goals vs. accomplishments. However, not all of the farmers who retrofitted their home also retrofitted their farm buildings (barns, etc.). The actual number that retrofitted both was quite small (N=18). Care must be taken when trying to determine the combined energy savings for each farm (home + farm buildings).

The expected outcomes of the project were to reduce the total energy use on at least 323 small animal farms and 100 farm homes by at least 8,000 kWh and 2,343 therms per farm. The farm retrofits, as noted above were only possible on 147 farms and 48 homes. The farm retrofits resulted in an annual energy savings of 7,403 kWh and 514 therms. The home retrofits resulted in electrical savings of 6,730 kWh and 141 therms per farm house.

Another measureable outcome of the project was to improve the environment by reducing annual fossil fuel emissions by 1,942 tons (of carbon dioxide equivalent). Much of the electricity in Missouri is produced by coal. Coal has approximately 2.1 pounds of CO_2 / kWh. This average annual kWh savings equates to a reduction of approximately 1,142 ton of CO_2 emissions / year. There are 161 pounds of CO_2 per 1 million BTU. Since a therm is 100,000 BTU, and we had a savings of 75,516 therms we can compute the CO_2 savings due to the annual reduction in therms. This equates to approximately 607 ton / year- thus a total savings of 1,749 tons of carbon dioxide equivalent were saved each year due to the farm retrofits.

The savings that resulted from the home retrofits were similarly calculated. The annual savings for the electrical for the home resulted in a reduction of approximately 332 ton of CO_2 emissions/year. The annual therm savings for the home retrofits was projected to reduce CO_2 emissions by approximately 54.5 ton CO_2 per year. The total energy savings from the home retrofits reduced the annual CO_2 emissions by approximately 387 tons of CO_2 per year.

The last measureable outcome associated with the MAESTRO project focused on the stimulation of the economy by creating or retaining jobs. The goal of the project was to create at least 69 jobs. Using the ACEE Energy Stimulus Jobs Impact Calculator developed in July of 2009, the MAESTRO team estimated that 11 new jobs were created in year one, 27 new jobs in year two, and 28 new jobs in year three.

Survey Results:
The MAESTRO survey was sent to every producer two weeks after their incentive check was mailed. The MAESTRO team used a scale of 1 to 5 where 1 represents 'not at all satisfied' and 5 represents 'extremely satisfied'. Over 50% of the surveys sent to producers that participated in the farm portion of the program were returned. The table below explains the average score received for each category.

Category Heading	**Average result**
The Ease of the Sign Up Process	4.43
Time it took to receive your Energy Management Plan/Technical Assistance Report	4.20
Time it took to complete the home audit report	4.29
Quality of your Energy Management Plan/Technical Assistance Report	4.36
Quality of your Home Audit Report	4.32
Overall experience with the program	4.40
Willingness to recommend the program to others	4.45
Knowledge of the University of Missouri Extension Associate	4.35
Knowledge of the home audit staff	4.43
The experience you had with the energy analyst (EnSave, Inc.)	4.51
The follow up once the Energy Management Plan/Technical Assistance Report was completed	4.28
The follow up once the Home Audit was completed	4.02
Usefulness of the farm audit	4.51
Usefulness of the home audit	4.25
The application process for final incentives (MASBDA)	4.36

Note: The program did not receive an average score lower than ‘4’.

Throughout the program the MAESTRO team received input from the farmers identifying additional benefits, above saving energy and money. Examples are:

- Producers expressed how installing certain equipment took the load off of other equipment (i.e. installing a plate cooler took load off of the compressors)
- Farmers expressed often running out of hot water but by installing the Compressor Heat Recovery unit that was resolved.
- Even with the low wattage on LEDs farmers are happy with the light emission.
- Farmers aren’t changing out bulbs as often, which makes farm managers happy.
- Poultry growers saw an increase in production (one became one of the top three producers for the month of September).
- Poultry numbers are increasing.

Challenges - Farm

6. Summary of project problems encountered:

The first challenge faced in MAESTRO was the farmers’ lack of interest in the loan program. The MAESTRO team shared this challenge with the US Department of Energy (DOE). DOE responded by allowing the team to reallocate funding in the budget to create a grant program. As discussed in the financial incentives section, the team made further adjustments to the out-of-pocket cost for audits and technical assistance, and increased available incentive funds in an effort to attract more participation.

Agriculture is always a challenging sector to reach because agricultural market prices are volatile and it lacks the predictability found in other industries. At the height of the program in 2011, Missouri saw two tornados, two major floods, a wind storm and prolonged drought. These natural disasters coupled with a national recession and record low prices in the dairy industry caused many producers to be unable to participate in the program due to lack of funds; their limited internal resources were used to pay bills or to respond to natural disasters.

The MAESTRO team developed a document titled “Considerations of Structure for Future Programs for Farm Energy Efficiency. The document in full can be found in Appendix D.

It should be noted that determining the energy footprint of a farm operation differs from an audit of the energy footprint of either a home or an industrial business. Some key issues that should be noted when conducting a farm energy analysis for a farm include:

a. Significant energy savings can be captured by not using a whole-building concept as is used in homes and apartment buildings. Lighting improvement is a particularly pertinent example of this situation. A “Technical Assistance” approach combined with full energy auditing, which was used in MAESTRO, can help address this situation.
b. Farm energy efficiency programs should have flexibility to focus on farm-specific measures such as installing a more energy efficient heating system.
c. Programs focused on small farms should leverage additional resources to help farmers pay for farm energy audits and upgrades. An example is leveraging financial assistance

through the USDA Natural Resources Conservation Service to help farmers afford their comprehensive farm energy audits and retrofits.

d. Where possible, farm energy incentives should focus on grants rather than loans since farmers already have access to loans or are reluctant to take on more debt.
e. Requiring a partial payment for services up front gives farmers more ownership in the process since they have money at stake.

Finally, our business plan began with loans that the farmer could **not** justify. We modified the plan by re-allocating the monies for loans to a grant program for the farmer. The cost of the grant program quickly made the project incentive poor, meaning we ran out of incentive funds long before we were able to reach out to all the livestock producers that qualified for the MAESTRO program.

Verification of Data - Farm

7. Evaluation of information collected:

Measurement and verification were conducted on a greenhouse, two dairy farms, one chicken farm and one swine farm. The MU Engineers learned that the sensors available for data acquisition systems were not suitable for verification of data in livestock facilities as the sensors had to be hard wired to the data acquisition system and the data saved onto a local computer (on site). Such a system was not suitable, since the farms are geographically dispersed and in remote areas. Thus a wireless EM&V system was developed, tested and established for monitoring energy usage during the project.

These systems allowed MU Engineers to verify that a variable speed drive in fact reduced the energy requirements for the milk transfer pumping operation on a dairy farm. They also verified that by installing a new standard vacuum pump the amperage usage was reduced by 35%. Please refer to the EM&V report in Appendix B where a detailed summary is provided on each of the farms where the cost savings were verified.

Program Sustainability Plans - Farm

8. Program plan for the post-grant period:

To help sustain the momentum of agricultural energy efficiency in Missouri during the post-grant program, the University of Missouri formed the Midwest Energy Efficiency Research Consortium (MEERC). Program details are summarized below, with a more detailed outline to be found in Appendix E.

MEERC's Vision: Be the strategic, solutions-oriented energy efficiency organization that will develop energy efficiency technology and at the same time educate citizens, businesses and industries about the economic and environmental benefits of energy efficiency.

MEERC's Goals: MEERC has three goals: to 1) Advance EE in the Midwest by increasing knowledge and understanding of EE in business, industry, agriculture and the public, 2) Assist EE business development and 3) Partner with industry to develop and advance EE technologies.

MEERC's Operation: The Director operates MEERC on a day-to-day basis. As an affiliated University of Missouri entity, the director incorporates the appropriate dimensions of a premier Land Grant University and member of the Association of American Universities (AAU) to focus on energy efficiency programs. An Internal Advisory Board consisting of individuals within the university with energy efficiency expertise guides the Director. An external advisory board consisting of members from the public and private sector who have knowledge and the capacity to advance the energy efficiency business provide critical and key direction to the MEERC Director.

MEERC's Capacity: The MEERC enables each separate university EE program at the University of Missouri to work together by forming "centers" that focus key strengths of their existing work. MEERC and its centers capitalize on the unique and comprehensive capacity of the university with its research, outreach and education capacity. MEERC is organized around six centers that focus on Midwest EE uniqueness: High Performance Buildings Center, Agricultural EE Center, Lighting Research Center, Low Energy Heating and Cooling Center, the Energy Solutions and Research Center, and the Water and Wastewater Center.

MEERC's Participants: MEERC is fully cognizant that energy efficiency is not achieved in an isolated academic environment. To effectively implement energy efficiency a partnership must be developed with other universities, technical colleges, national associations, EE centers, government agencies, utilities, and the business and industry sectors of our economy. Some of these partnerships already exist and others are being pursued as opportunities arise.

Final Technical Report - Home

9. Home Energy:

The Home Energy report is based on collaboration among team members in Housing and Environmental Design Extension in Human Environmental Sciences Extension at the University of Missouri. In addition, third-party professional energy auditors conducted residential energy audits

Several incentive plans were devised to facilitate the adoption of energy saving equipment for the farm home (see Appendix A). In March of 2011, the cost of the home assessments to the farmer was cut in half. Seven months later (October, 2011), a 75% cost-share was extended to homes with a limit set at $3,000. At the same time, the cost-share for farms was raised to $12,000. A cost-share maximum of $20,000 was therefore possible with a farm and home combination. Five months later the MAESTRO team increased the one-time cost-share for homes to 90% and raised the limit to $8,000. Also at this time, a $20,000 cost-share maximum was made possible for farms that saved a minimum of 10,000 kWh. This resulted in a $28,000 maximum possible when the farm 90% cost-share was combined with residential 90% cost-share. In addition, MASBDA offered to provide 25%-40% of project funding up front. This was on an as-needed basis to get projects started in cases where a contractor required 50% down and customers had a hard time getting the money together.

During the MAESTRO project, a total of 106 home energy audits were conducted throughout the State of Missouri. MAESTRO conducted 104 and two were leveraged through DNR. To qualify for retrofit funding, an audit recommendation of at least 15 percent estimated energy savings was required. Of the 106 audits conducted, 48 completed their upgrade installations. Additional homes would have been retrofitted if additional grant funds had been available. The total number of farmers who retrofitted both the farm buildings and the home of the farmer was 18.

Among the 106 homes that received a home energy audit, the overall savings' estimates per home are illustrated in Table 1: Audit-based Energy Savings Estimates/Home.

Table 1: Audit-based Energy Savings Estimates/Home

	ELECTRICITY (n=99)		NATURAL GAS (n=4)		PROPANE (n=58)		% TOTAL ENERGY SAVED (n=106)
	Estimated kWh Saved	% kWh Saved	Estimated ccf Saved	% ccf Saved	Estimated Gallons Saved	% Gallons Saved	
Avg/Home	5,209	20	10,346	8	163	15	27
Max/Home	25,667	70	15,598	10	1,093	72	90

The pre-retrofit estimated total electrical energy saved was 515,686 kWh, 41,382 ccf of natural gas, and 9,454 gallons of liquid propane gas per year.

The annual projected energy savings after retrofits had been completed among those participants who qualified with at least an estimated 15 percent energy savings potential are illustrated in Table 2: Post-retrofit Energy Savings/Home.

The total electrical energy saved (post-retrofits) was projected at 323,029 kWh, 33,416 ccf of natural gas, and 7,046 gallons of liquid propane gas.

Table 2: Post-retrofit Energy Savings/Home

	ELECTRICITY (n=48)		NATURAL GAS (n=2)		PROPANE (n=26)		% TOTAL ENERGY SAVED (n=48)
	Estimated kWh Saved	% kWh Saved	Estimated ccf Saved	% ccf Saved	Estimated Gallons Saved	% gallons Saved	
Avg/Home	6,730	23	16,708	11	271	18	34
Max/Home	27	80	25,548	16	1,508	72	86
Totals	323,029		33,416		7,046		

The characteristics of a typical home in the project provided a useful 'snapshot' or 'profile' of the environmental context in which the participants reside. These figures are approximations. The mean area of the typical home was approximately 2,266 square feet, while the smallest home area was 625 square feet and the largest 5,550 square feet. The mean home age was 47 years old, while the newest home was one year old and the oldest home was 132 years old. The mean annual amount of energy savings in dollars/home was $776.43, while the lowest annual savings was $232 and the greatest annual savings was $3,408. The mean percent of annual energy savings (post-retrofit) was 34 percent, with 15 percent annual savings being the lowest percent saved, and 86 percent annual energy savings as the highest among participants.

The merits of improving the energy efficiency of farm homes were weighed against the more immediate need to keep livestock fed and watered during a drought. The costs of such unanticipated expenditures also slowed participants' progress through the audit-to-retrofit process compared to what one might expect under less stressful circumstances. Nowhere is this more evident than when one examines the length of time participants were engaged in the project (from energy audit through retrofit). The mean length of time from start to finish for a retrofit was 11 months, with the shortest time being four months and the longest one year and 10 months.

Accomplishments -Home

10. Comparing accomplishments with the goals and objectives of the project:

The objectives for the home retrofits were an integral part of the farm retrofits. These were to strengthen the financial viability and environmental soundness of Missouri's small animal farms by helping them implement energy efficient technologies for the production facility, farm buildings, and the homes on these farms.

The expected measurable outcomes of the project were to improve the environment and stimulate the economy by:

- Reducing annual fossil fuel emissions by 1,942 metric tons of carbon dioxide equivalent, reducing the total annual energy use on at least 323 small animal farms and 100 farm homes by at least 8,000 kWh and 2,343 therms per farm.
- Stimulating the economy by creating or retaining at least 69 jobs, and saving small animal farmers an average of $2,071 per farm in annual energy expenditures.

The milestones that were achieved were presented in the accomplishments section for the Farm. However, please note the overall goal of the MAESTRO project was a 15 percent reduction in energy use -- the home retrofits exceeded that goal, yielding an overall annual energy consumption reduction (post retrofit) of 34 percent/home.

The pre-retrofit estimated total electrical energy saved was 515,686 kwh, 41,382 ccf of natural gas, and 9,454 gallons of liquid propane gas. The actual total electrical energy saved (post-retrofits) was 323,029 kwh, 33,416 ccf of natural gas, and 7,046 gallons of liquid propane gas. These data are best reviewed in Table 2. Post Energy Retrofit Savings/Home.

Private contractors conducted energy audits and as such, jobs were created. The home retrofits resulted in materials that were purchased and installed locally, thereby an economic benefit to the communities in which the participants lived. However, a less tangible yet profound benefit to the local and regional communities is a result of University Extension's mission – to educate.

Challenges - Home

11. Summary of project problems encountered:

One of the earliest challenges encountered was in the quest for uniformity among the third-party audit contractors. There were 152 auditors on the Department of Natural Resources (DNR) list of approved BPI certified home auditors. All 152 were contacted and offered the opportunity to participate as contractors in the MAESTRO program, 20 signed agreements, and 16 performed audits for the Project. Because each was a certified energy auditor, it was assumed that there would be a common set of energy audit outcomes, a shared audit protocol. This was not the case. In the more rural areas of the State, the auditors' reports were more general than those found among auditors located in more populated areas. This lack of consistency and specificity resulted in follow-up with auditors far more frequently than if explicit protocols had been identified at the outset of the project.

The challenge faced when comparing the auditors' reports primarily concerned the level of specificity or precision used in determining audit results. In many of the most rural areas, auditors were simply unaccustomed to the level of precision required by the grant. The reports generated could be best categorized as 'estimates.' The lack of precision required the Home team to track-down the utility company supplying energy to the home, identify their utility rates at the time of the audit and then apply this data to a data-driven model established by those auditors who operated at the required level of quantifiable data rather than generalized estimates thereby creating data consistency across all audit reports. This process was both unanticipated and time consuming. The argument that the more rural auditors made has validity: they simply did not typically operate at the required level of precision required and felt that complying with the grant request for greater rigor fell beyond their responsibilities. Some of the auditors would have been reluctantly willing to 're-audit' at the level of precision required, but not for the fee that was offered to them. That alternative was discussed among the Home team members who felt that it was unlikely that an acceptable level of report consistency was achievable unless those requiring the precision actually followed-up on generating it. It should be noted, that overall, the estimates were relatively accurate representations of the energy consumption issues -- they simply were not in a data-identifiable form.

The recession, also contributed to the participation in this part of the project. A monetary incentive for the project changed twice over the course of the project (See Appendix A). While the monetary incentives for home energy retrofits were being increased, the incentives for farm energy retrofits were escalating to an even higher level. Participation increased, but these incentives flat-lined due to a fixed budget for retrofits. As a result, the number of 'fundable' retrofits was by necessity reduced. A total of 48 of the 106 homes that were audited implemented energy efficient equipment.

In spite of the problems encountered, several benefits were observed. For example due to the use of the blower-door technology, sources of air infiltration were precisely identified. MAESTRO determined that the reduction of unwanted air infiltration (air leaking into and out of the home) was the single most significant contributor to improved energy inefficiency among the home energy audits. As a result, if Missouri farm homeowners were in a position to undertake a single, most efficient strategy for improving energy efficiency, we can now say that reducing air infiltration (particularly within older farm homes) would be the place to begin. Adding insulation would run a close second, followed by replacing single-paned windows and un-insulated doors, acquiring Energy Star-rated household appliances, replacing the hot water heater, replacing heating and/or cooling systems, and replacing incandescent lighting with either compact fluorescent bulbs or LED bulbs. These recommendations are based on MAESTRO Project findings. In addition, the expected energy and dollar savings resulting from actions taken on these recommendations can also be calculated derived from MAESTRO project findings.

Savings realized for the average farm home in the program more than doubled the minimum 15 percent required energy savings averaging a reduction of 34 percent reduction over the existing energy bills. The savings equated to 6,730 kWh and 141 therms per farm house.

Program Sustainability Plans - Home

12. Program plan for the post-grant period:

As a result of the information gleaned from the home energy audits, the Housing and Environmental Design Extension team is in a position to provide research-based information to the citizens of Missouri that is both timely and relevant. The housing retrofit strategies that lead to parsimonious allocation of resources are one of the most significant outcomes of this project.

The first-hand knowledge in the preceding paragraph will enhance the delivery of energy efficient systems instructional material. The Housing and Environmental Design Extension team is now in a position to provide research-based information to their students as well as the citizens of Missouri that is both timely and relevant. The HES team will present these findings at state and national extension meetings and in their classrooms. Findings from the MAESTRO program are also being used in the creation of a “Master Builder” program that will provide continuing education to builders across Missouri and will in large part address how energy improvements can benefit both builders and homebuyers.

Verification of Data - Home

13. Evaluation of information collected:

As a result of the diversity among energy auditor’s reports, the lack of data uniformity and consistency demanded closer examination. While this strategy proved to be quite efficient and ‘fair’, it served as yet another set of opportunities for inconsistency. At the conclusion of the project the data was reviewed and reassessed using a uniform set of criteria. The information presented is this report is based on those modifications.

Developed Products – Farm and Home

14. Products developed under the award:

A. Publications

1. Sunrise Farms Case Study – A MAESTRO publication
2. Murray Volk Case Study – A MAESTRO publication
3. Using Technology to Serve Agricultural Producers with Energy Audits. ASABE Publication #12-1336794. Presented in Dallas, July, 2013

4. Masters of Energy And Sustainability ASABE Publication # 12-1336857 Presented in Dallas, July, 2013
5. MU Guide Sheets – for Farm and Ranch (in development). Appendix F
6. EnSave Fact Sheets – Appendix G
    - MAESTRO Brood Curtains
    - MAESTRO Compressor Heat
    - MAESTRO Milk Pump VSD
    - MAESTRO Milk Vacuum Pump
    - MAESTRO Milk Precooler
    - MAESTRO Scroll Compressor
    - MAESTRO Stock Waterer
7. MAESTRO Best Practices Guide – Appendix G
8. Ranking guide-used to prescreen producers to estimate if farm will benefit from a farm energy audits

B. Web site or other internet site

- http://extension.missouri.edu/energy/Your%20Farm.html
- http://www. moagenergysavings.com – note you can only get to this website via the MEERC website

15. Networks or collaborations fostered

The partnership/network began when two government entities sat down side by side and questioned if the Missouri Extension Service within the state could/should respond to the DOE request for proposals. Meetings were next staged with the faculty from the College of Agriculture, Food and Natural Resources, Human Environmental Sciences, and Engineering. This team immediately partnered with and at the same time enlisted the help of EnSave, a nationally recognized farm energy auditing and implementation firm. EnSave, Inc. had been conducting energy audits for well over 20 years and was a good partner for the project.

The final team (Missouri Department of Agriculture, University of Missouri (MU), College of Agriculture Food and Natural Resources, MU Extension, MU College of Human Environmental Sciences, MU College of Engineering, MASBDA and EnSave, Inc.) began forging networks with:

- NRCS- Natural Resources Conservation Service
- AECI – Associated Electric Cooperative Inc.
- REC – Local Rural Electric Cooperatives
- USDA – United States Department of Agriculture
- Missouri Soybean Association
- Missouri Corn Growers
- Missouri Pork Producers Association
- Missouri Beef Producers
- Missouri Dairy Producers Association
- Missouri Farm Bureau
- MFA Inc. – Formerly Missouri Farmers Association

16. Technologies/Techniques

- Farm Shop Energy Analysis Tool – author, Joe Zulovich. MU Extension

17. Inventions/Patent Applications, licensing agreements

- No inventions or patents nor licensing agreements were developed.

18. Other products, such as data or databases, physical collections, audio or video software or netware, models, educational aid or curricula, instruments or equipment

- http://www.youtube.com/watch?v=M_tw3ZzWcaM

Appendix A

Timeline of MAESTRO Incentives
10/18/12

May 2010

Original Incentives

- Energy assessments offered for the farm and home at reduced cost
- Rebate of energy assessment cost when recommended equipment is installed
- Interest rate buy-down to 3% or equivalent amount as a cash down payment
- 75% loan guarantee

January 2011

- Program kick-off event with the Governor

March 2011

- 75% cost-share up to $5,000 for farms
- Home assessments reduced from $250 to $125
- Farm assessments (EMP) reduced from $500 to $250
- Free single practice assessments (TA) introduced

August 2011

- State Fair promotion offered whole farm (EMP) assessments with no deposit

October 2011

- 75% cost-share extended to homes with limit set at $3,000
- 75% cost-share for farms raised to $12,000
- $12,000 cost-share maximum possible with farm and home combination

March 2012

- Home cost-share increased to 90% and raised to $8,000
- Farm cost-share remained at 75% up to $12,000
- $20,000 cost-share maximum possible with farm and home combination
- Farms that save at least 10,000 kWh eligible for 90% cost-share up to $20,000
- $28,000 maximum possible when combined with residential 90% cost-share
- MASBDA offered to provide 25%-40% of project funding up front. This was on an as-needed basis to get projects started in cases where a contractor required 50% down and customers had a hard time getting the money together.

October 2012

- The interest Buy Down and Down Payment Grant were unavailable after October 1.
- No new Loan Loss Reserve applications were accepted after October 1.

MAESTRO Process:

1. Clients contacted EnSave at 800-732-1399 to have an initial assessment completed to determine whether the farm was eligible to participate in the MAESTRO program. If so, then the farm contact information was sent to MU Human Environmental Services staff to identify whether a farm home energy audit was appropriate for the farm operation.
2. If appropriate, the farm home energy audit was completed.

To participate in the Energy Management Plan (EMP) or Technical Assistance (TA), an eligible farmer:

1. Contacted EnSave at 800-732-1399 to have an initial assessment completed to determine whether an EMP or TA was appropriate for the farm operation.
2. NOTE: The EMP was completed in accordance with the American Society of Agricultural and Biological Engineers (ASABE) Standard 612, on the farm.

NOTE: To receive any of the following incentives, qualifying energy retrofits as recommended by a TA, EMP or Home Energy Audit must have had at least a combined energy savings of 15% or more. Certification of Implementation reports were prepared by University of Missouri Extension staff (Agricultural or Human Environmental Sciences as appropriate) upon completion of an on-site project checked out to make sure that all practices had been properly and completely installed and were operational.

To participate in the home audit rebate program, an eligible farmer:

1. Submitted a rebate and implementation grant application.
2. Implemented one or more of the home audit finding(s) from which the combined energy savings realized is 15% or greater.
3. Provided equipment invoices and a Certification of Implementation on a form provided by MASBDA.
4. The farmer was then rebated the amount paid to the home audit firm but not to exceed $125 for the farm home audit.

To participate in the EMP rebate program, an eligible farmer:

1. Submitted a rebate and implementation grant application.
2. Implemented one or more of the EMP finding(s) from which the combined energy savings realized is 15% or greater.
3. Provided equipment invoices and a Certification of Implementation on a form provided by MASBDA.
4. The farmer was then rebated the amount paid for the EMP but not to exceed $250.

To participate in the Implementation Grant program the farmer:

NOTE: Only practices implemented on the farm (not farm home) as described in TA or EMP were able to qualify for this incentive when it was first instituted (See Timeline of MAESTRO Incentives

1. Submitted a rebate and implementation grant application.
2. MASBDA reviewed the application and pre-approve the project for an Implementation Grant.
3. MASBDA issued a letter to the applicant stating the pre-approved project, amount, and deadline by which the project must be completed.
4. Submitted invoices and a Certification of Completion before the deadline provided in the letter. Once all information was received and approved, the grant was issued.

To participate in the Interest Buy Down program or Cash Equivalent Down Payment program an eligible farmer:

1. Obtained initial financing approval from a Missouri lender. The loan could not exceed $50,000.
2. Lender and borrower submitted an Application for Interest Buy Down/Down Payment Grant.
3. Lender financing could not exceed the bank's normal and customary interest rate for a loan of this type and underwriting requirements. NOTE: Only those energy saving technologies identified in an approved home audit, TA or EMP qualified for this program.
4. Terms (length) of the loan were based on energy savings but in no event could the loan exceed the sooner of 10 years or the useful life of the equipment installed.
5. Farmer was given the option of an interest buy down to a 3 percent loan or the equivalent dollar amount as a cash down payment.

   For example: $25,000 loan at a 6.5% normal interest, 5 year terms, with monthly payments would equal $4,349.26 in interest. Same loan at 3% interest would equal $1,953.02 in interest. If the borrower selects the Interest Buy Down option, the lender would receive a payment in the amount of $2,396.24 ($4,349.26 - $1,953.02).

   If the borrower selected the Cash Down Payment option, the lender could receive a payment in the amount of $2,396.24 and the loan would be for $22,603.76 at 6.5% for 5 years.
6. Lender received notification from MASBDA as to the status of the application and available funding prior to loan closing.

NOTE: The interest buy-down or equivalent cash down payment was processed upon MASBDA receiving proof of the loan. (Promissory Note)

To participate in the Loan Loss Reserve (75 % loan guarantee on loans not to exceed $50,000) the lender and borrower:

1. Submitted an application for Loan Loss Reserve.
2. Provided proof of collateral interest.

    - A lender’s favorable analysis of the borrower’s ability to repay the loan,
    - Current financial statement , not more than 90 days old, including profit and loss statement and cash flow statement, and
    - Credit Bureau report, if required by the lender.
3. Lender will receive notification from MASBDA as to the status of the application and available guarantee funding prior to loan closing.
4. Lender will be issued a Certificate of Guarantee.
5. Lender reports annually 120 days after the end of each calendar year while this certificate is in effect. The report will include borrower’s (a) current balance sheet, (b) outstanding loan principal balance, and (c) loan payment status.

Appendix B

EM & V Summary Report

MAESTRO: Report on Evaluation, Monitoring & Verification Activities

June 25

2013

By developing a new Evaluation, Monitoring and Verification (EM&V) system a study was undertaken to investigate the energy efficiency of agriculture facilities in the state of Missouri. A wireless EM&V system was developed, tested and established for monitoring energy usage over a period of time. A greenhouse, poultry farm, dairy farms, and a swine farm were instrumented and their processes evaluated for energy efficiency.

Appendix B – EM & V Summary Report
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1. Farm Energy Audit Process

The goal of the energy audit is promoting the energy efficiency of the farm. For operating the farm as efficiently as possible and determining the actual and verifiable reduction in the farm's current energy use the data is gathered on site and then recommendations are provided based on engineering calculations which include finding energy saving opportunities associated with the technologies, cost savings, and payback period.

1.1. EM & V Equipment

By using an **Evaluation, Monitoring and Verification (EM&V)** system a study was undertaken to investigate the energy efficiency of agriculture facilities in the state of Missouri. However, the available sensors and data acquisition systems were not suitable as the sensors had to be hard wired to the data acquisition system and the data saved on to a local computer at the site. Since the farms are by nature very distributed and far apart and in remote areas, such a system was not suitable. Thus a wireless EM&V system was developed, tested and established for monitoring energy usage over a period of time.

Based on a wireless sensor network platform the EM&V system can monitor the assets or environment reliably with spatially distributed measurement sensors connected to nodes that transmit data wirelessly through the internet or mobile phone to a remote gateway connected to a host computer. The sensors have been implemented to measure temperature, pressure, voltage, power factor, humidity, illumination of light source, ammonia, air or liquid velocity etc., in the form of analog data. The nodes gather the analog data and convert this data to digital signals which are transmitted through a Gateway to the lab computers/server, which can be hundreds of miles away. National Instrument (NI) products have been chosen to create a system to monitor energy consumption as shown schematically in figure 1.

The block diagram of the system is as below:

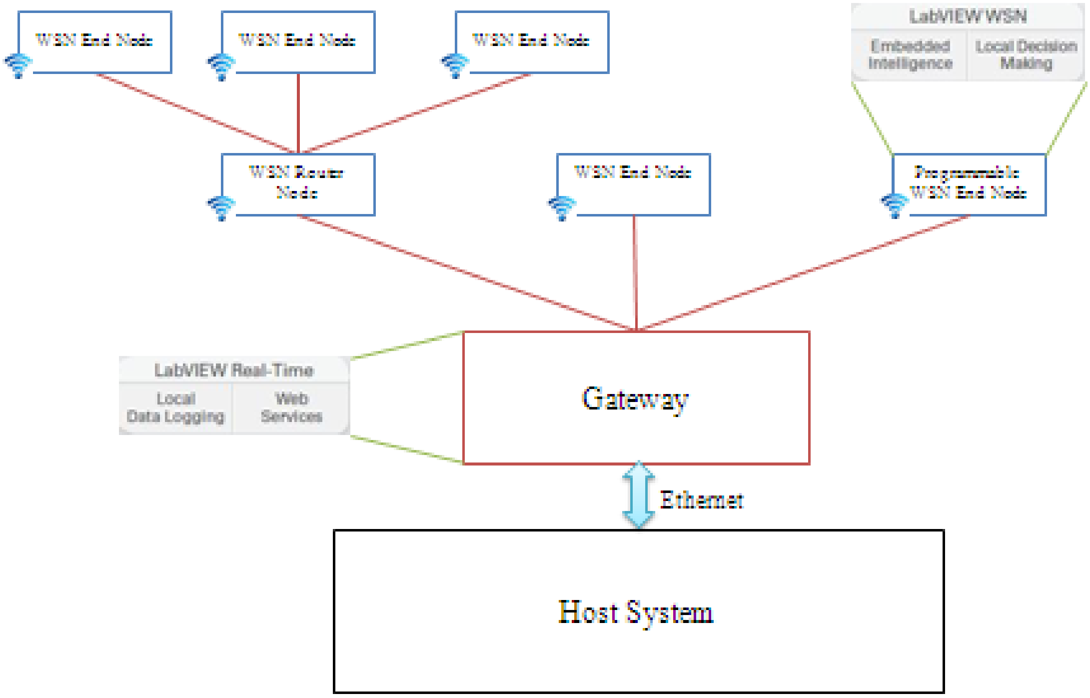


Figure 1 Block diagram showing the arrangement of the components in a wireless EM&V system. Some

of the sensors used are shown below in Figure 2.

Light Sensor Anemometer Current Sensor

Figure 2: Sensors used in EM&V

A node can be visualized as shown in Figure 3, while the gateway is shown in Figure 4. Figure 3 shows a National Instrument’s (NI) WSN-3226 Programmable Voltage/Resistance Input node which is able to measure potential differences or resistances across terminals.

Figure 3 NI WSN-3226 Voltage/RTD combination node

For coordinating communication between nodes and transferring data to host computers two types of NI gateways are used. Figure 4(a) shows the WSN-9791 Ethernet Gateway which requires a host computer and Figure 4(b) illustrates the WSN-9792 Programmable Gateway which stand-alone device that does not require a host.

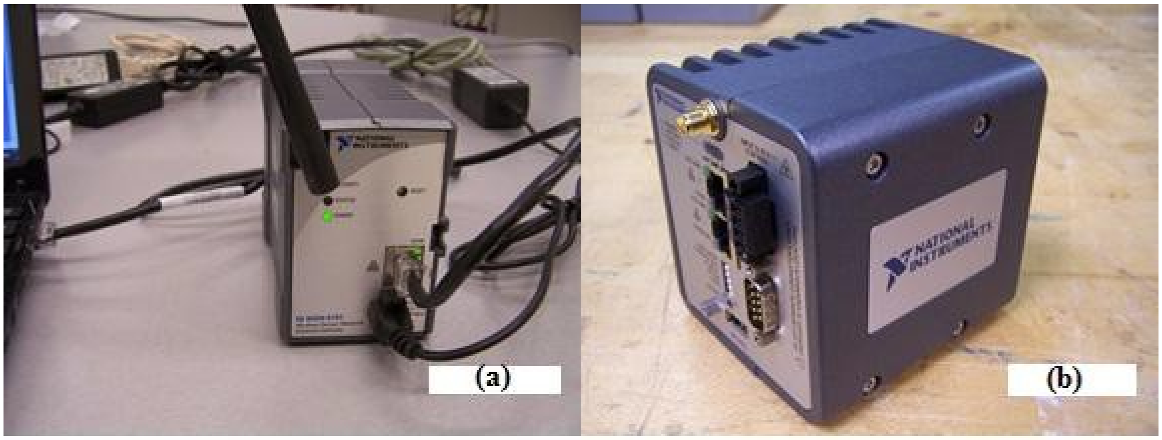


Figure 4 (a) WSN-9791 Ethernet Gateway, (b) WSN-9792 Programmable Gateway

The existing system is set up to run with a LabVIEW program with a graphical interface that displays real-time data. Moreover, as a system-check and vitals of the system the Measurement and Automation program is used. The gateway and host system memory capacity determine how many data can be stored in the system. The gateway will continue to collect and store the data until the memory is full. When the buffer memory is full, it wraps around to overwrite the oldest data first and data can be stored in the system until whenever you want. This Wireless Sensor Network has the ability to create smart WSN systems with the NI LabVIEW WSN Module; also, can provide increased flexibility and lower costs. Therefore, it can be a very effective tool in monitoring energy use and improving energy efficiency. When compared to other wireless systems network for monitoring energy efficiency, the National Instrument devices have higher performance and flexibility. Moreover, 10’s to 100’s of sensors can be used simultaneously. NI recommends the programmable versions of both nodes and gateways.

The complete details of the equipment set up and installation are provided in Appendix A.

2. Green House Case Study

2.1. Experimental Setup

Energy efficiency study of a greenhouse located in High point, MO, was undertaken. The greenhouse consists of three buildings each of size 96 ft. length, 30 ft. width and 14 ft. height. The wireless sensor network consisted of the following main components;

- The spatially distributed measurement nodes interface with sensors nodes to monitor the relative humidity, air velocity and temperature of inside the greenhouse, also the air handler and water heater currents used in the greenhouse. These nodes transmit acquired data wirelessly to gateway
- The Gateway coordinates communication between nodes and transfers data to host system
- A Host system, which collects data from gateway, records files, process, analyze, and present the measurement data by using software installed on it
- LabVIEW and Measurement & Automation programs are the main software which were installed on the host computer
-

2.2. Results and Discussion

Figures 5-8 display relative humidity, air velocity, temperature, air handler and water heater current versus time, respectively.

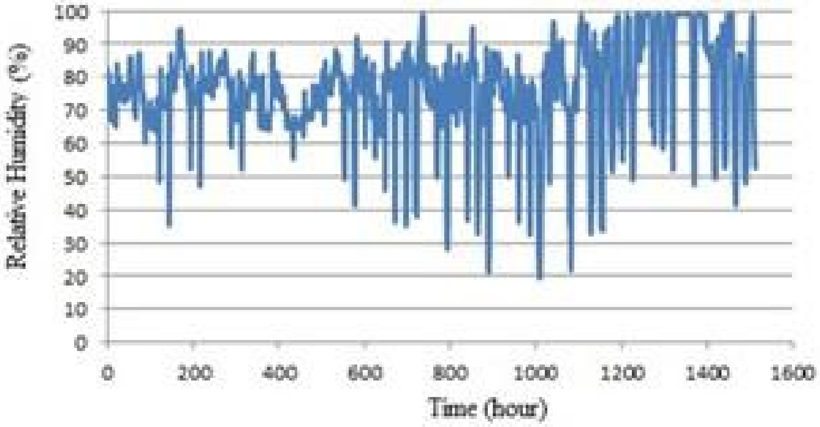


Figure 5: Relative humidity (%RH) vs. time

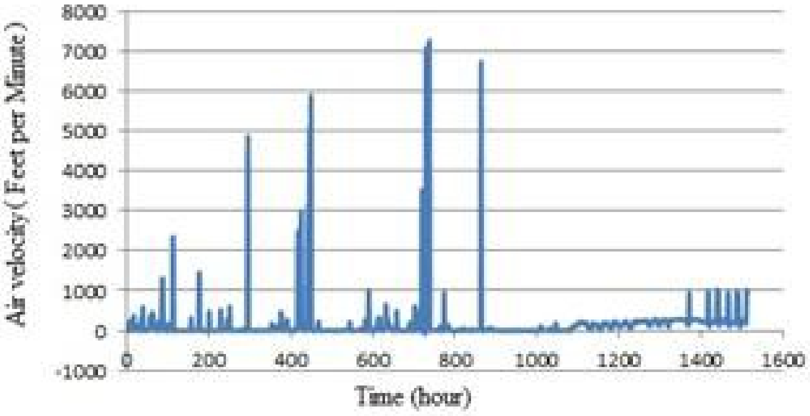


Figure 6: Air velocity in ft/min versus time

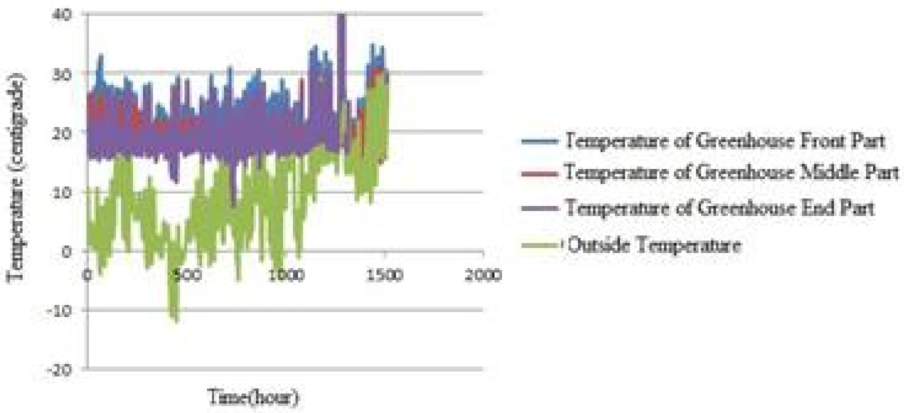


Figure 7: Temperature vs. time

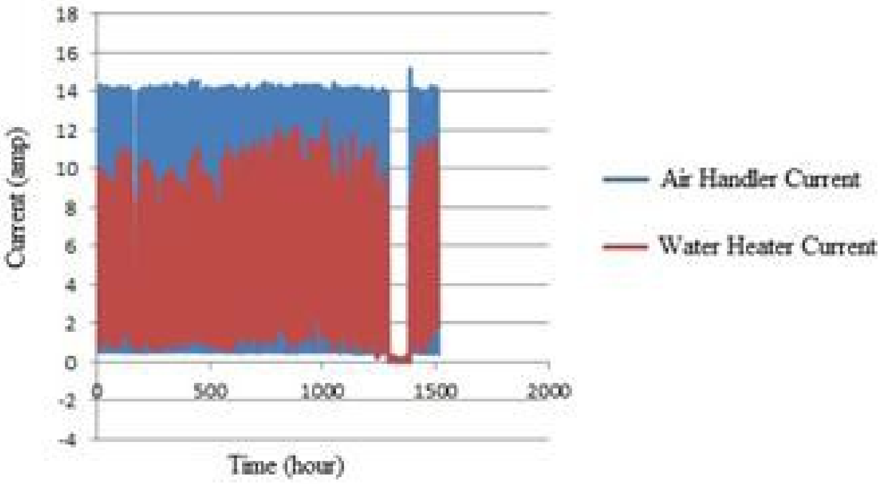


Figure 8: Air handler and water heater current vs. time

Usually 70- 80% of energy consumed in greenhouse is for space heating by natural gas or propane, and 10- 15% is electricity. According to figure 7, during the cold weather the temperature difference between inside and outside of the greenhouse is high and thus the heat loss from greenhouse is significant, which growers should try to address. The current roof in this case study is a single layer polyethylene and should be replaced with a polyethylene film with infrared red (IR) coating, which will reduce the heat loss by 25-30% without loss of sun light transmission. The roof can also have an anti-condensation (AC) coating, which decreases the amount of water vapor that accumulates on interior glazing surfaces and in this way fewer water droplets fall on crops below and less light is blocked compared to a plastic film covered with water droplets. Although IR-AC films are typically 15 percent more expensive than standard plastic films, the return on investment is typically about one-two years while the roof materials lasts for about four years.

3. Lenz Dairy Farm Case Study

3.1. Experimental Setup

The milking process consists of harvesting milk from the dairy cow and transporting the milk to a bulk tank for storage. This process can take place one or two or more times per day and most dairies schedule their lactations for a continuous milk supply throughout the year. On average, milking utilizes 18 per cent of the electrical energy use on a dairy farm (Peterson, 2008) [1].

Figure 9: Lenz diary’s 10 HP and 7.5 HP vacuum pumps which operate during milking and

equipment washing are often the primary electrical energy users

During the milk harvest and equipment washing the vacuum pumps (Figure 9) can consume 20% to 25% of all electrical energy use on a dairy farm. Four main types of vacuum pumps exist that include sliding vane rotary pumps, watering pumps, rotary lobe (blower) pumps and turbine pumps. Each of these operates and uses energy differently. Vacuum pumps become less efficient as the vacuum level increases (Ludington et al., 2004). Hence, for conserving energy the vacuum pump should operate at lower vacuum levels as possible.

Lenz Dairy Currently operates one 10 horsepower vacuum pump and one 7.5 horsepower vacuum pump for 240 minutes per day during milking and wash cycles. The milk transfer pump is a 1hp motor that operates about 330 minutes per day. By installing the current sensors, the current usage of the vacuum pumps and milk transfer pump was measured. In addition, the temperature sensors detect the temperature of ambient air, the wall of the bulk storage tank, inlet water to tank and outlet water vapor from tank.

3.2. Results and Discussion

Lenz Dairy has three opportunities to improve the energy efficiency of its milk vacuum pump system. According to Figure 10 the amperage used by 10hp and 7.5hp vacuum pumps was 37 Amp and 28 Amp, respectively; whereas the amperage usage by the new standard 10hp and 7.5hp vacuum pumps are about 13 Amp and 10 Amp, respectively. Therefore, by installing new standard vacuum pumps the amperage usage will reduce by 65% for each vacuum pump. Moreover, the installation of a variable speed drive (VSD) on the vacuum pumps is recommended. A variable speed drive is a piece of equipment that regulates the speed and rotational force, or torque output, of an electric motor. This equipment adjusts the speed of the pump motor to deliver no more than is actually needed [2]. The energy savings is from the reduced demand of the vacuum pumps. Figure 11 shows the amperage usage by a 10hp vacuum pump with VSD installed on it. By comparing the amperage usage of 10hp vacuum pump between Figure 10 (without VSD) and Figure 12 (with VSD), it is concluded that VSD reduces the amperage usage by 46%. Check with a licensed electrician to determine if the farm's wiring will accommodate a VSD. Using a variable speed vacuum pump is one of the better investments you can make for the dairy.

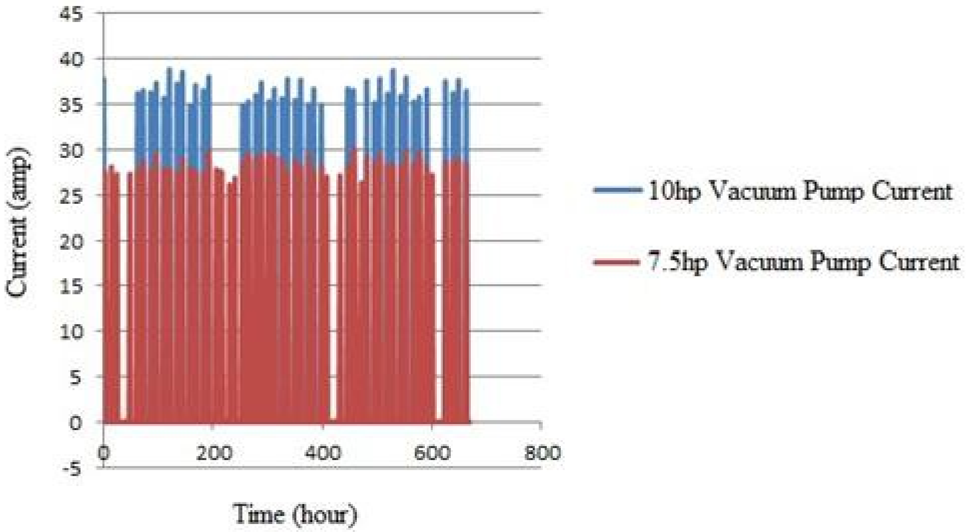


Figure 10: The current usage of 7.5 HP and 10 HP vacuum pumps with time

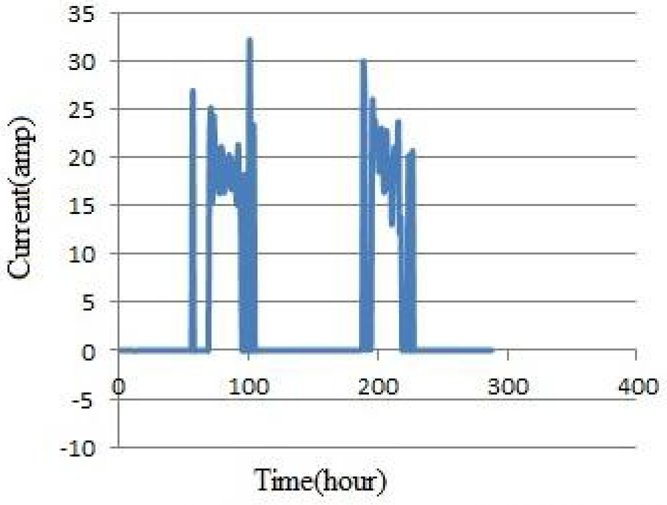


Figure 11: The current usage of a 10HP vacuum pump with VSD installed on it vs time.

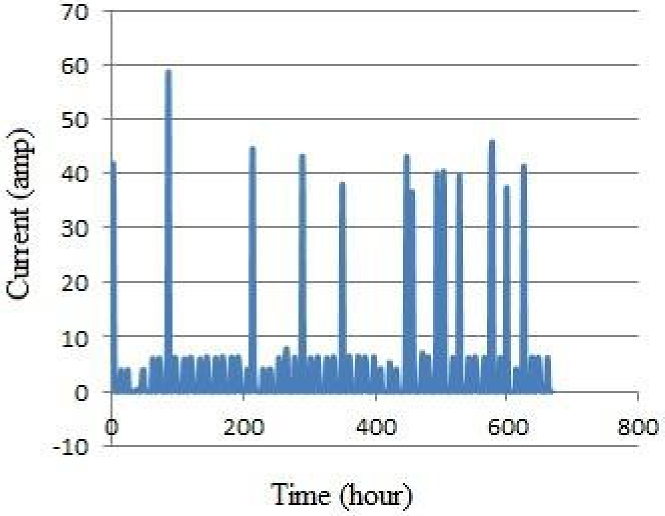


Figure 12: Milk transfer pump current versus time

According to figure 12 the milk transfer pump has a pick current which is about 42 Amp; hence, by installing a variable speed drive (VSD) on the milk transfer pump the amperage usage can be reduced. Studies have found that energy use by milk transfer pump can be typically reduced by

60 percent when VSD is installed

Figure 13 displays a comparison of the existence vacuum pump system in the Lenz Dairy and the proposed new standard vacuum pump motor electricity usage and Figure 14 shows a comparison of the current and the proposed milk transfer pump motor electricity usage with a VSD installed. Table 1 provides economic details for these recommendations, the average electricity cost has been considered as $0.076 per kWh.

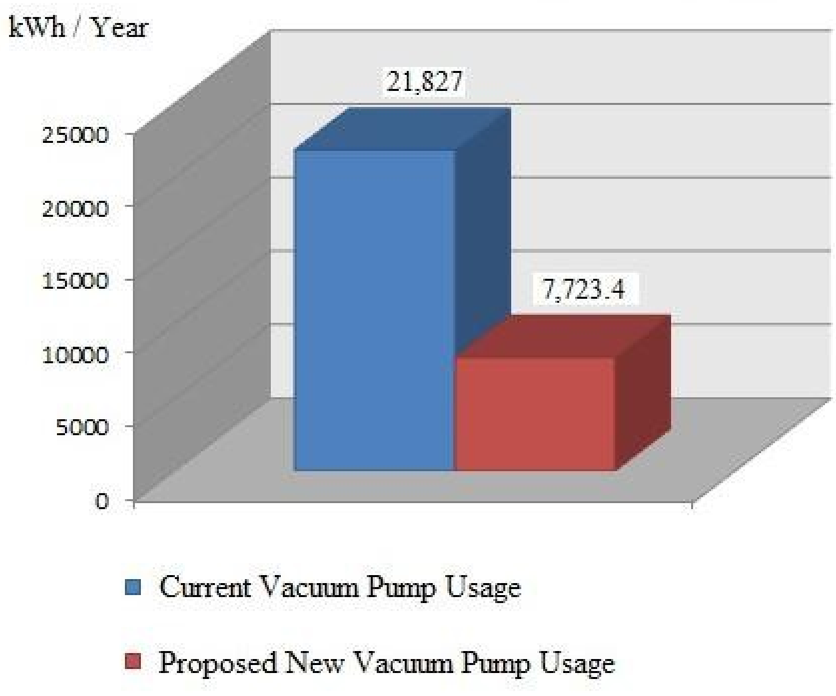


Figure 13: Vacuum pump electricity usage

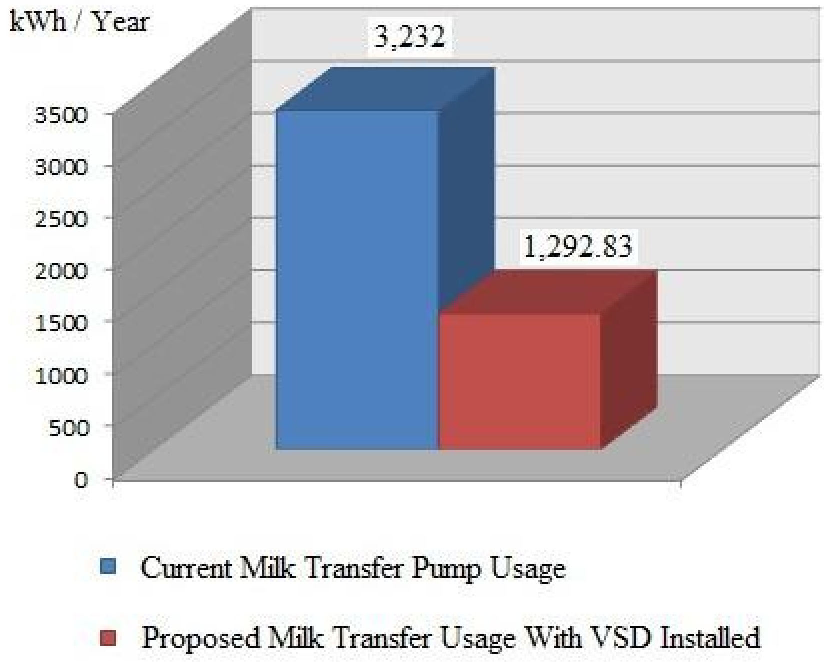


Figure 14: Milk transfer pump electricity usage

Table 1. Recommended energy saving equipment and energy savings

Recommended Equipment	**Current Annual Usage (kWh)**	**Estimated Annual Electricity Savings (kWh)**	**Estimated Annual Energy Cost Savings**	**Estimated Cost to the Farm**	**Estimated Payback in Years**	**Percent Savings (%)**
New Standard 7.5hp & 10hp Vacuum Pumps	21,827	14,103.6	$1,071.9	$15,000	14.0	64.61
New Standard 7.5hp & 10hp Vacuum Pumps with VSD	21,827	17,656.36	$1,341.9	$16,000	11.9	80.10
Milk Transfer Pump VSD	3,232	1,939.17	$147.4	$1000	6.8	60

Lenz Dairy cools milk by using an open well water chilled plate cooler for pre-cooling, as well as additional cooling that takes place in the bulk tank during and after each milking. The cooling tank was monitored and Figure 15 shows the position of the temperature sensors of the inlet water from chiller to bulk tank, outlet water vapor from bulk tank, the wall of bulk tank and ambient air. Temperatures have been measured and results are displayed in figure 16, 17 and 18.

Fig. 15 The position of temperature sensors

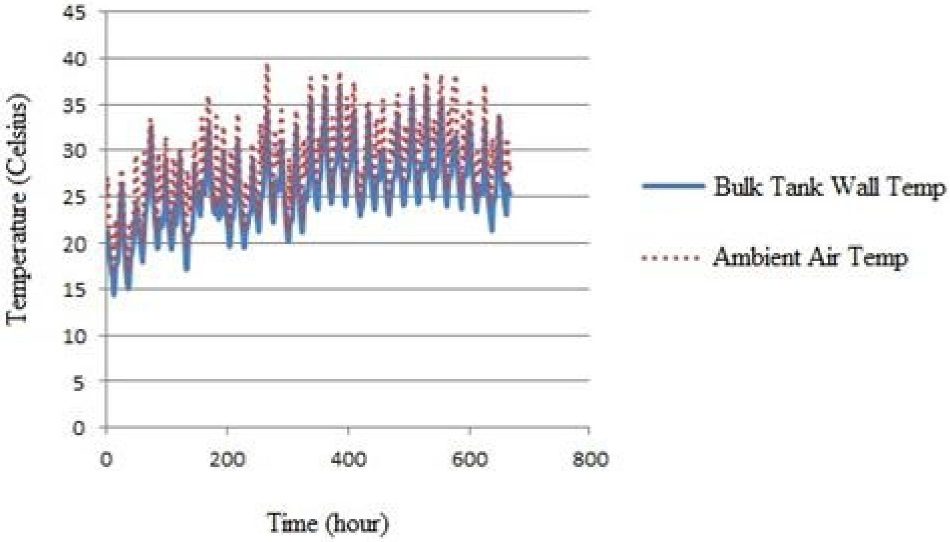


Figure 16: Bulk tank wall temperature and ambient temperature versus time

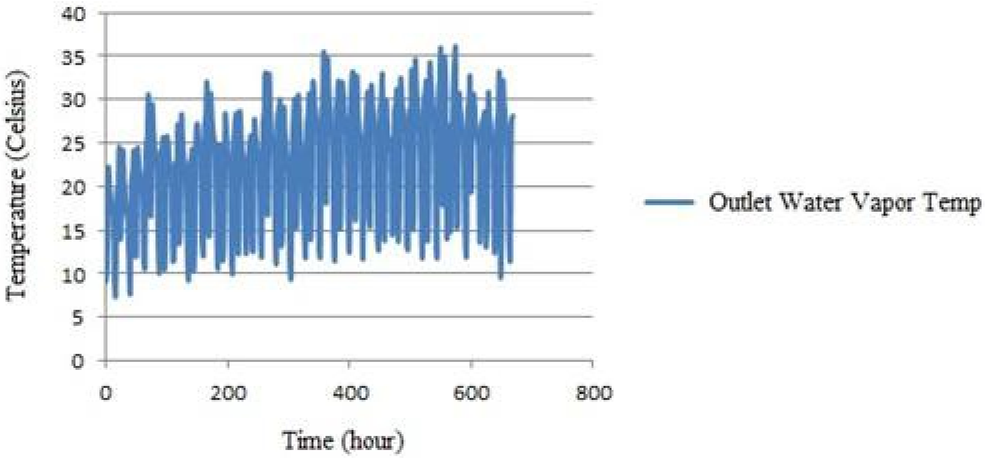


Figure 17: Outlet water temperature versus time

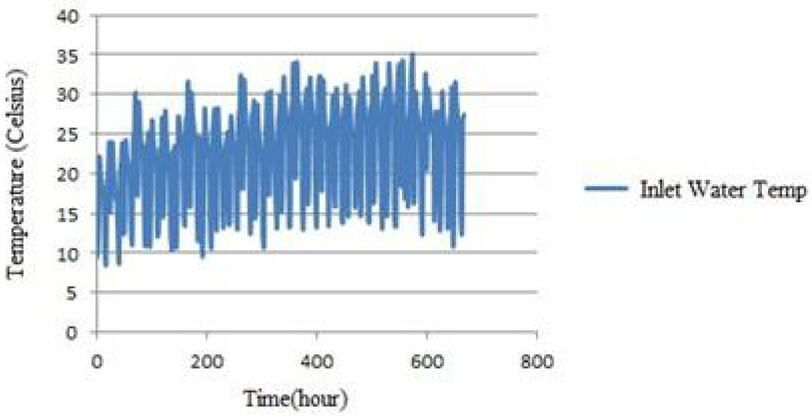


Figure 18: Inlet water temperature versus time

A milk cooling tank, also known as a bulk tank or milk cooler, consists of an inner and an outer tank, both made of high quality stainless steel. The space between the outer tank and the inner tank is isolated with polyurethane foam [3]. Since temperature difference between ambient air and the wall of bulk tank is less than 5 degree, installing an external insulation over bulk tank would not be cost effective for Lenz Dairy.

4. Linn Missouri Dairy Farm Case Study

4.1. Experimental Setup

Linn Missouri Dairy currently operates a 10 horsepower (HP) vacuum pump with variable speed drive (VSD) installed on it for 6 hours per day during milking and wash cycles. The milk transfer pump is a 1 hp motor that operates 6 hours per day. The current draw of vacuum pump and milk transfer pump are monitored by installing the current sensors.

4.2. Results and Discussion

Linn Missouri Dairy has two opportunities to improve the energy efficiency of its milk vacuum pump system. According to Figure 19 the amperage usage by 10hp vacuum pump with installed VSD is about 20 Amp whereas the amperage usage by new standard 10hp vacuum pump is about 13 Amp. Therefore, by installing new standard vacuum pump the amperage usage will reduce by 35%.

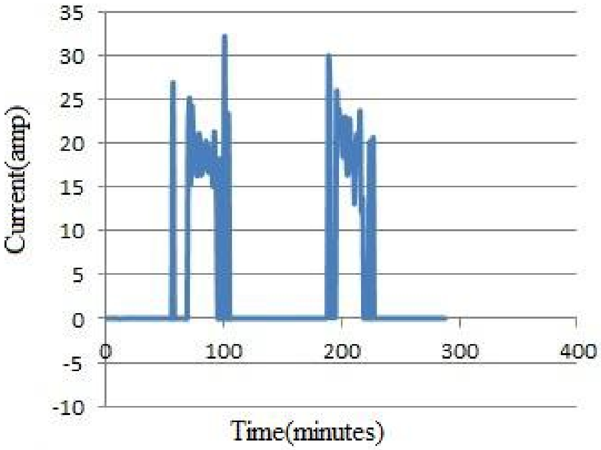


Figure 19: The current usage of a 10 HP vacuum pump with VSD installed on it versus time

(measured for 24 hrs at 5 min intervals)

According to figure 20 the milk transfer pump has a pick current which is about 9 Amp; hence, the installation of a variable speed drive (VSD) on the vacuum pumps is recommended. A variable speed drive is a piece of equipment that regulates the speed and rotational force, or torque output, of an electric motor. This equipment adjusts the speed of the pump motor to deliver no more than is actually needed [5]. The energy savings is from the reduced demand of the milk transfer pumps. Studies have found that energy use by milk transfer pump can be typically reduced by 60 percent when VSD is installed. Making a variable speed milk transfer pump is one of the better investments you can make for the dairy.

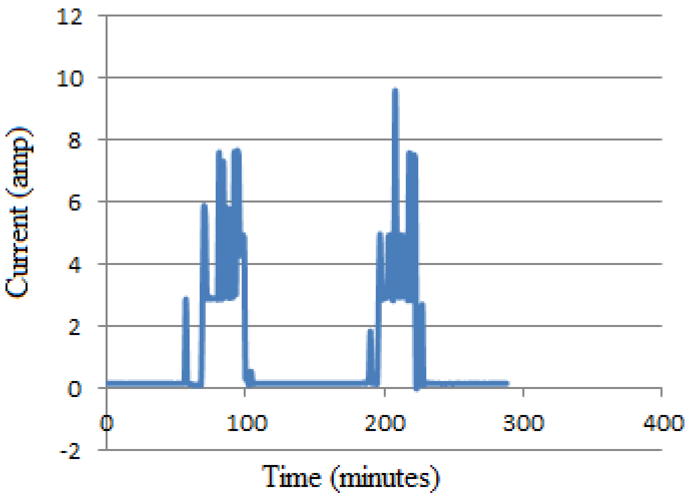


Figure 20: The current usage of a 10 HP vacuum pump with VSD installed on it versus time (measured for 24 hrs at 5 min intervals)

Figure 21 displays a comparison of the existing vacuum pump system in Linn Missouri Dairy and the proposed new standard vacuum pump motor electricity usage and Figure 22 shows a comparison of the current and the proposed milk transfer pump motor electricity usage with a

VSD installed. Table 2 provides economic details for these recommendations, the average electricity cost has been considered as $0.076 per kWh.

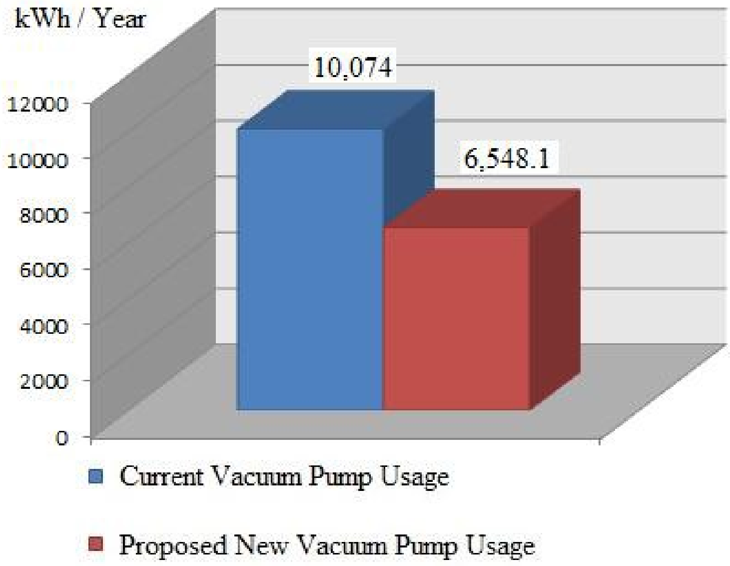


Figure 21: Vacuum pump electricity usage

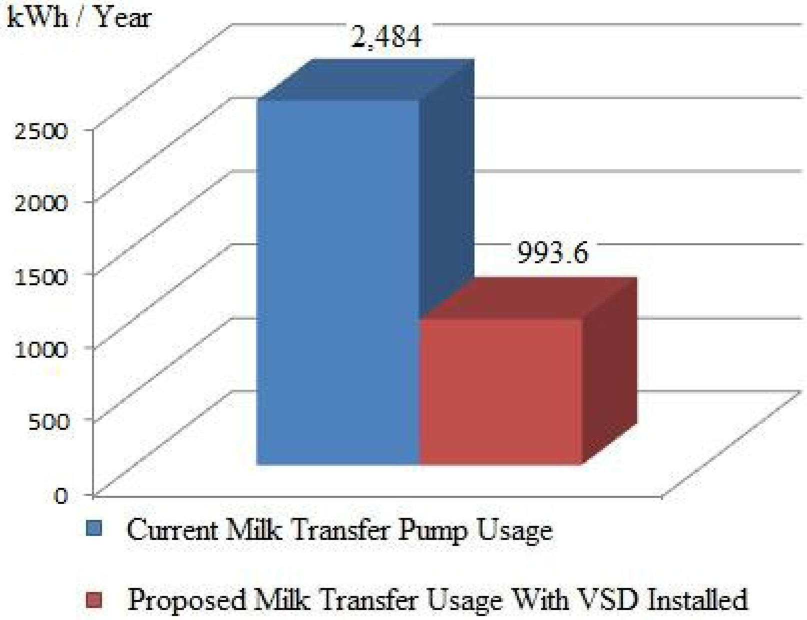


Figure 22: Milk transfer pump electricity usage

Table 2. Recommended Energy Saving Equipment and Energy Savings

Recommended Equipment	**Current Annual Usage (kWh)**	**Estimated Annual Electricity Savings (kWh)**	**Estimated Annual Energy Cost Savings**	**Estimated Cost to the Farm**	**Estimated Payback in Years**	**Percent Savings (%)**
New Standard 10hp Vacuum Pump	10,074	3,525.9	$268	$9,000	33.6	35
Milk Transfer Pump VSD	2,484	1,490.4	$113.3	$1000	8.82	60

5. Wayne Hentges Chicken Farm Case Study

5.1. Experimental Setup

Wayne Hentges chicken farm which is located in Tipton, Missouri, operates four poultry houses where 5.5 flocks are raised every year with approximately 23,800 birds per flock per house. Annually, a total of 523,600 birds are raised at this location. The birds are in the houses for about 40 days (Figure 23). The target growth weight for the birds is seven pounds when they are shipped to Tyson, the farm’s integrator [6].

Figure 23: Wayne Hentges chicken farm [6]

All of the houses are tunnel ventilated. Current draw was measured for the tunnel fan, four exhaust fans and lighting per each poultry house by installing the current sensors. Moreover, the temperature at different locations was monitored by temperature sensors connected to the nodes.

5.2. Results and Discussion

Figure 24 and 25 show the amperage draw by tunnel fans and exhaust fans in two of the houses, respectively.

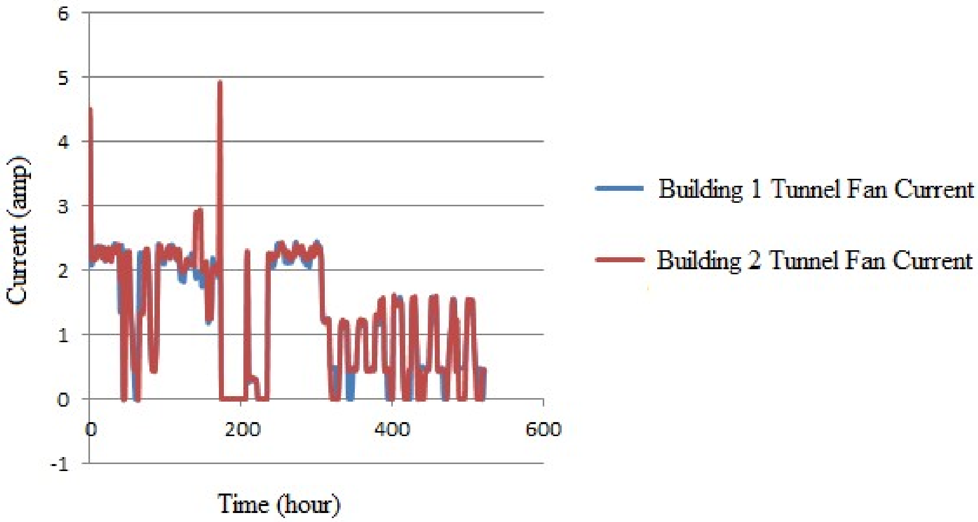


Figure 24: Buildings 1 and 2 tunnel fan current versus time

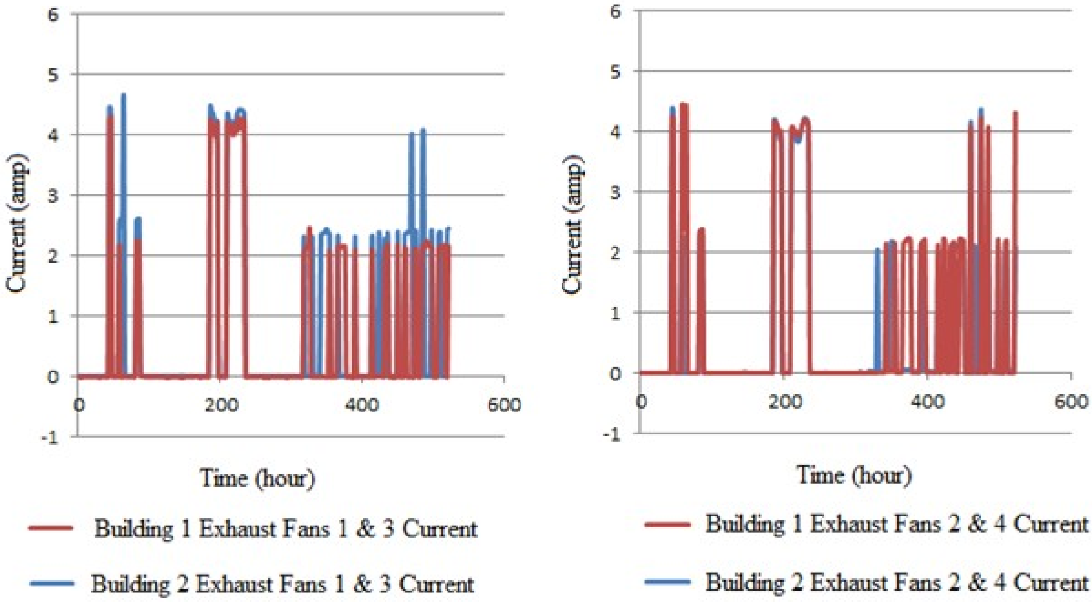


Figure 25: Buildings 1 and 2 exhaust fan current versus time

Besides decreasing the energy cost, for creating a healthy environment for poultry and associated farm workers high efficient fans, which is one of the components of mechanically ventilated facilities, plays a significant role in the poultry houses. Based on air delivery and efficiency ratings at 0.10 inches of water fans should be chosen. Choosing fans which are within the upper quartile of rated fan efficiencies listed in the table 3 for different fan sizes can be an effective decision based on Ref. [7] which indicates buying less expensive fans is often a poor economic choice. Although fan with higher energy efficiency would be more expensive, the payback for energy efficient fans is often short enough.

Diameter of fan	Efficiency rating	
Inches	**Median rating** cfm/W	**Top ¼ rating** cfm/W
<16	7.9	8.7
16 to 20	10.3	11.2
22 to 35	13.0	14.6
36 to 46	15.9	17.2
48 to 56	18.9	20.4
>56	20.1	21.5

Table 3 Fan test results for efficiency based on fan size and 0.10 inches of H_2O [2]

Not only the operating a high efficient fan has a noticeable effect on energy usage by poultry house but also the management of fans specially during the winter impacts the efficiency of the heating energy used within the building [8]. Establishing a weekly fan cleaning schedule and regular maintenance can keep shutters operating at their manufactured level of efficiency. Air delivery can be decreased by 40% due to dirty shutters and blades [8]. Worn belts and pulleys reduce the fan efficiency by 10-30% [6].

For two poultry houses the temperature at four different locations was measured and shown in figure 26.

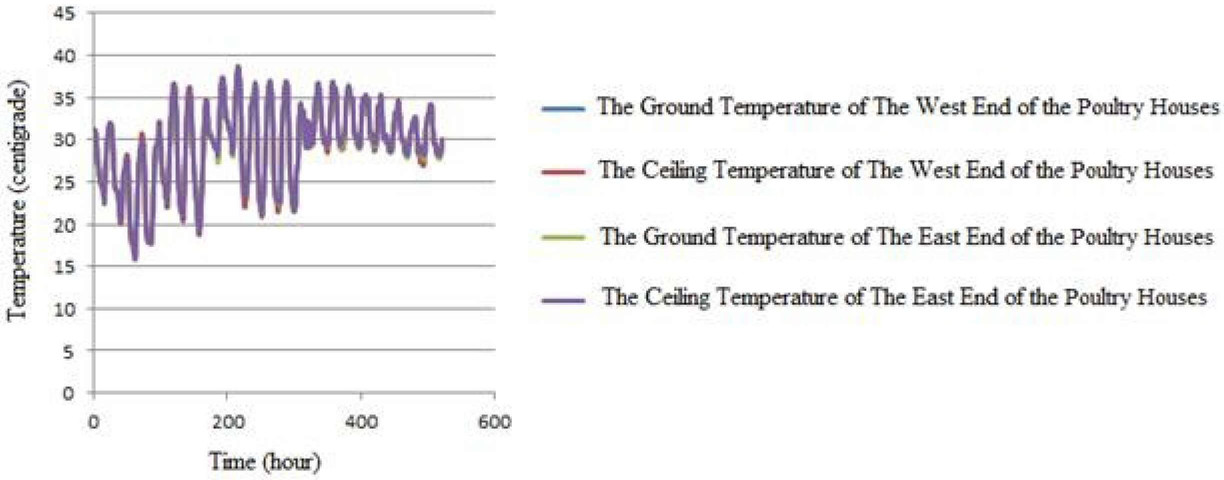


Figure 26: Temperature of the four different locations of the poultry house versus time

Both overheating and getting cold affect the performance of poultry houses negatively. Operating high efficient heating system and installing effective insulation with appropriate R-value on the walls such as side walls, end wall, knee walls, ceiling and brood curtains can keep the poultry house temperature in a favorite level and increase the energy saving and productivity benefits. Also, for having better control on air flow and reducing the level of energy usage for heating and relative humidity consequently better bird performance sealing the air leak is recommended [9].

Because of short payback period and easy replacement, Lighting can be one of the most attractive energy efficiency upgrades [6]. Figure 27 illustrates the lights current usage versus time for one poultry house.

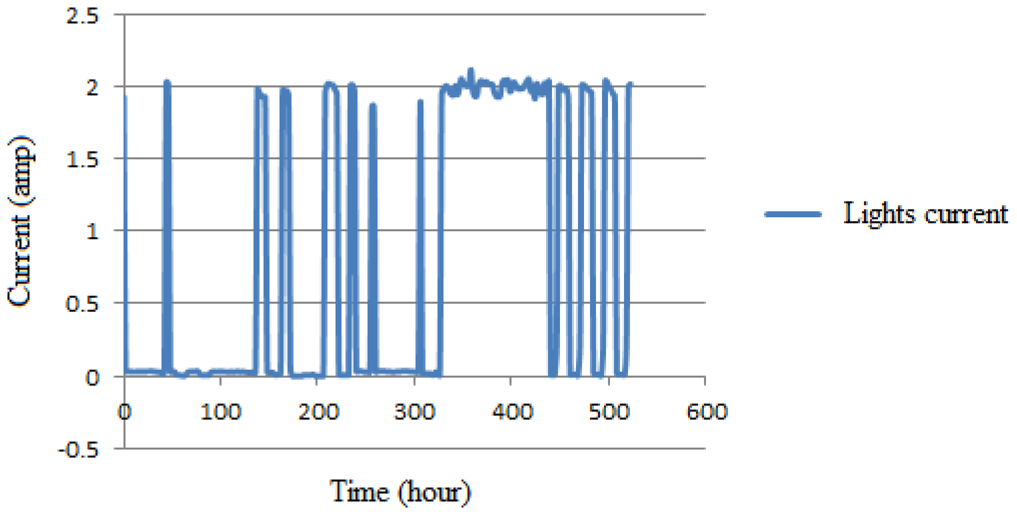


Figure 27: Current draw by lighting vs time

Installing high efficient Lights such as LED lights is recommended.

6. Bill Kessler’s Swine Farm Case Study

6.1. Experimental Setup

The EM& V equipment was installed in one of the houses of the Bill Kessler’s Farm located in the Mexico, MO, for monitoring energy usage. It is a swine farm with 14 houses that produces about 10,000 hogs per year in a cage free farrowing stall environment [10]. On a swine farm the energy mainly used for heating the farrowing and first stage weaner houses, ventilation systems and fans, lighting throughout the buildings, feed delivery and mixing, power-washing, and manure pumps to mix and agitate slurry tanks [11]. The mentioned house in the Bill Kessler’s Farms includes two and two of fans for mechanical ventilation, Two 3/4 horsepower feed motor for distributing the food inside the building and 20, 23-watt compact fluorescent lights (CFLs) and 6, 125-watt heat lamps. The current sensors are installed to monitor the current draw by these facilities separately.

6.2. Results and Discussion

Figure 28 shows the total current usage versus time for one building in the Kessler farm.

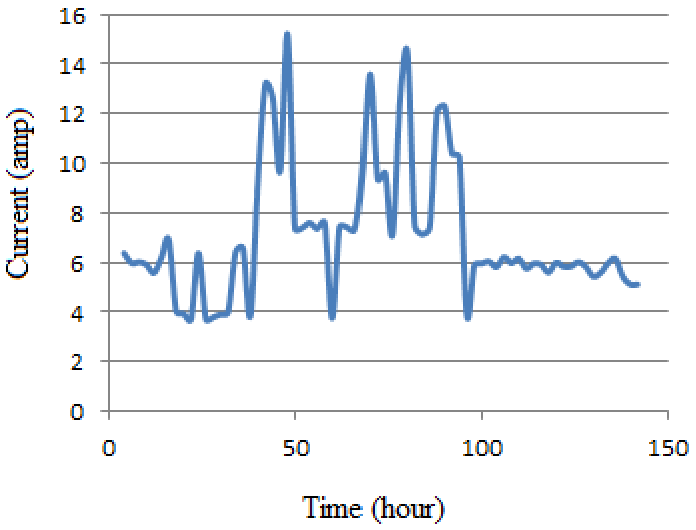


Figure 28: Total current usage of the building versus time

Controlling the levels of gases such as carbon dioxide, ammonia, methane and hydrogen sulphide in the pig’s environment has significant effect on the growth performance. Hence, air ventilation is a critical issue for such a farm. The building of Kessler farm in which the EM& V equipment was installed has Mechanical ventilation includes two of and two of fans. Figure 29 displays the summation of current usages of one of and one of fan which are operating simultaneously versus time.

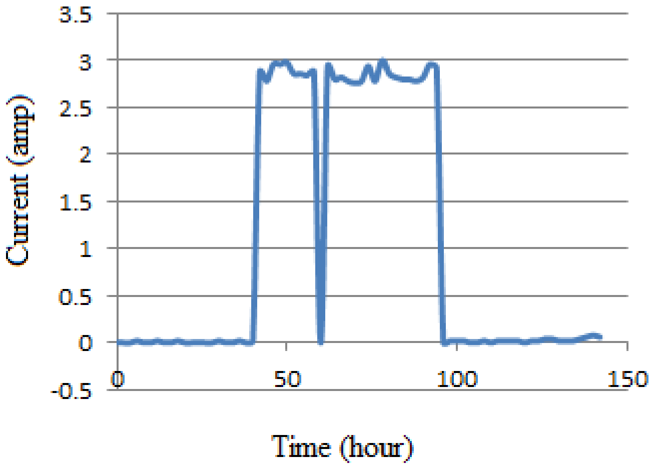


Figure 29: Summation of the current used by a 36-in and 48-in fan

Installing variable speed control for fans can reduce the energy usage. The recommendations which are provided for increasing the efficiency of mechanical ventilation of the Wayne Hentges chicken farm can be applied also for the fans which are used in the Kessler swine farm. Reference [10] mentions that when the payback period resulted in fan replacement is less than 10 years, replacing the fan is recommended and it occurs when the fan is more than five years old and runs for at least 3,000 hours a year. However, since the fans on Bill Kessler's farm are operated less than 3,000 hours per year, replacing them has a payback greater that ten years so it is not recommended.

The feeding system is one of the main users of energy in the swine farm. Two 3/4 horsepower motor are operated for distributing the food inside the building. Figure 30 shows the current usage by these motors. Since motors are small (3/4 HP), the current usage by feed motors is very low which is shown in figure 30. Also, they do not operate for a sufficient number of hours annually. Because of these two reasons motor replacement is not recommended.

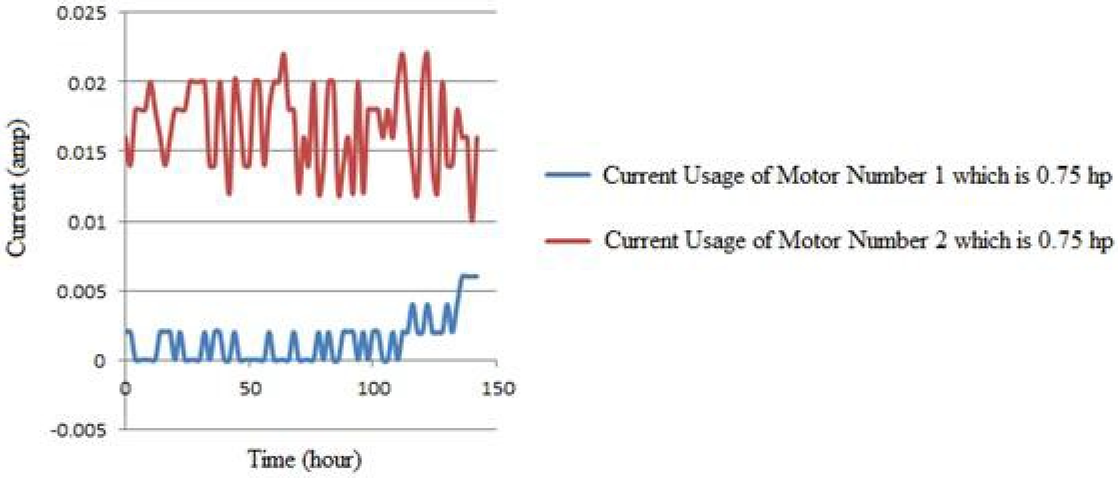


Figure 30: Current usage of feed motors vs time

The house operates 20, 23-watt compact fluorescent lights (CFLs) and 6, 125-watt heat lamps. The Figure 31 shows current usage by CFLs and heat lamps.

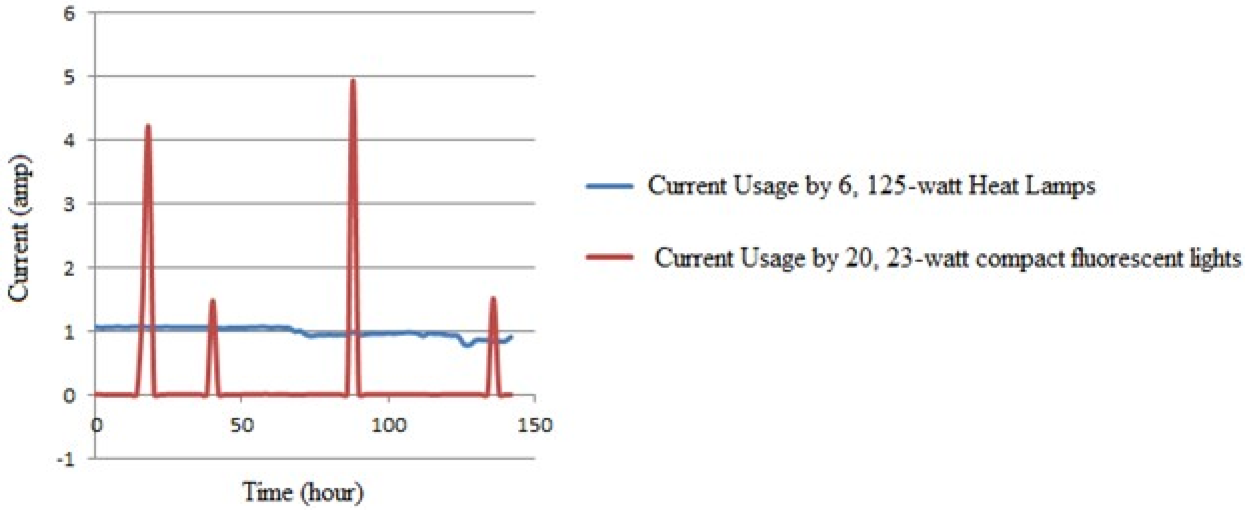


Figure 31: Current usage by lights and heat lamps versus time

Reference [10] measured that replacing the heat lamp with heat mat has 57.9 years payback which is so long so it is not recommended.

7. References

[1] http://www.thecattlesite.com/articles/2342/energy-effieciency-on-dairy-units [2] EnSave, Inc “Farm Energy Management Plan to Brandt Dairy” October 201. [3] http://en.wikipedia.org/wiki/Bulk_tank

[4] http://www.wisconsinpublicservice.com/business/vacuum_pump.aspx

[5] EnSave, Inc “Farm Energy Management Plan to Brandt Dairy” October 201.

[6] Energize Missouri agriculture, Sunrise farms case study, Missouri Department of Natural Resources

[7] Selecting Tunnel Ventilation Fans, Published by Penn State University, College of Agriculture Science, Cooperative Extension

[8] Energy efficient fans for poultry production, Iowa State University, University Extension

[9] Farm Energy Audit Report to John Sample by EnSave, Inc 2009

[10] Farm energy management plan submitted to Bill Kessler, EnSave Inc, 2011

[11] http://www.thepigsite.com/articles/4149/energy-use-on-irish-pig-farms

8. Summary:

A new energy monitoring system was established based on analog sensors and wireless transmission of acquired data after converting to digital signals. The evaluation, monitoring and verification (EM&V) system developed is very robust and flexible. Each channel transmitting data can be programmed in LabView and the system can be adapted as needed since it is made in-house. In this development and its application four undergraduate students and one graduate student from the college of engineering were involved and they gained very valuable experience, which they can use where ever they are employed. A user manual has been developed which details all the steps to establish a new EM&V system. Moreover, this wireless EM&V system is sophisticated and generic so that it can be used in other sectors besides agriculture, such as in industry and residential/commercial buildings.

Since the EM&V system was established from scratch in-house a significant amount of financial resources and effort was required. Never-the-less it provides greater flexibility in programming and installation compared to off the shelf commercial systems.

APPENDIX B

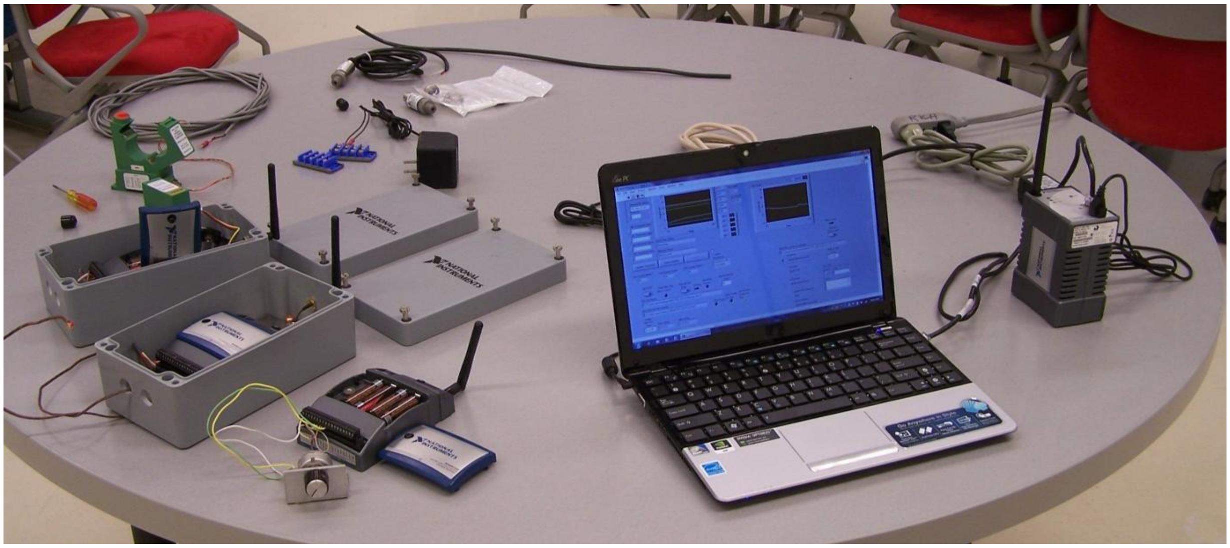
EM&V Equipment Setup and User Manual

Evaluation, Monitoring & Verification

Manual for Energy Consumption Monitoring System

By:

Prof. Sanjeev K. Khanna
Jeffrey Burman Adam
Hensel
Kyle Nordike
Richard Oberto



Acknowledgements: We would like to acknowledge the support of Dr. Robert Reed, Dr. Leon Schumacher, Mike Carraher, and Milad Yarali. Their support and advice made this project possible.

Financial support of MAESTRO and College of Engineering is appreciated.

Appendix B – EM & V Equipment Setup and User Manual

Table of Contents

Introduction

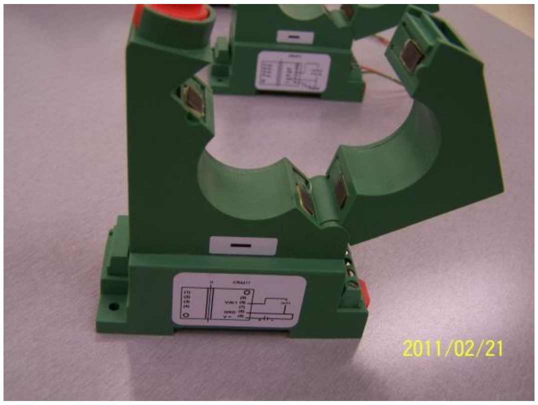
National Instrument products have to be chosen to create a system to monitor energy consumption. The sensors have been implemented to measure voltage and temperature; however, various other properties can be measured with the proper equipment.

Hardware

The following equipment is included in the current system:

Nodes: wireless devices that measure and transmit data to gateway. Additionally, nodes may be used to extend range from the gateway (mesh networking).

- WSN-3202 Programmable Analog Input
    - measures voltage with non-invasive sensor



2011/02/21

- WSN-3212 Programmable Thermocouple Input
    - measures temperature with thermocouple wire


NATIONAL INSTRUMENTS
TC
3
2011/10/03

- WSN-3326 Programmable Voltage/Resistance Input
    - capable of measuring potential differences or resistances across terminals

Gateway: coordinates communicate between nodes and transfer data to host.

- WSN-9791 Ethernet Gateway
    - requires a host computer
- WSN-9792 Programmable Gateway
    - stand-alone device that does not require a host

Host: collects data from gateway and records files. Files are then emailed for off-site data analysis.

- Laptop

- Cell phone modem

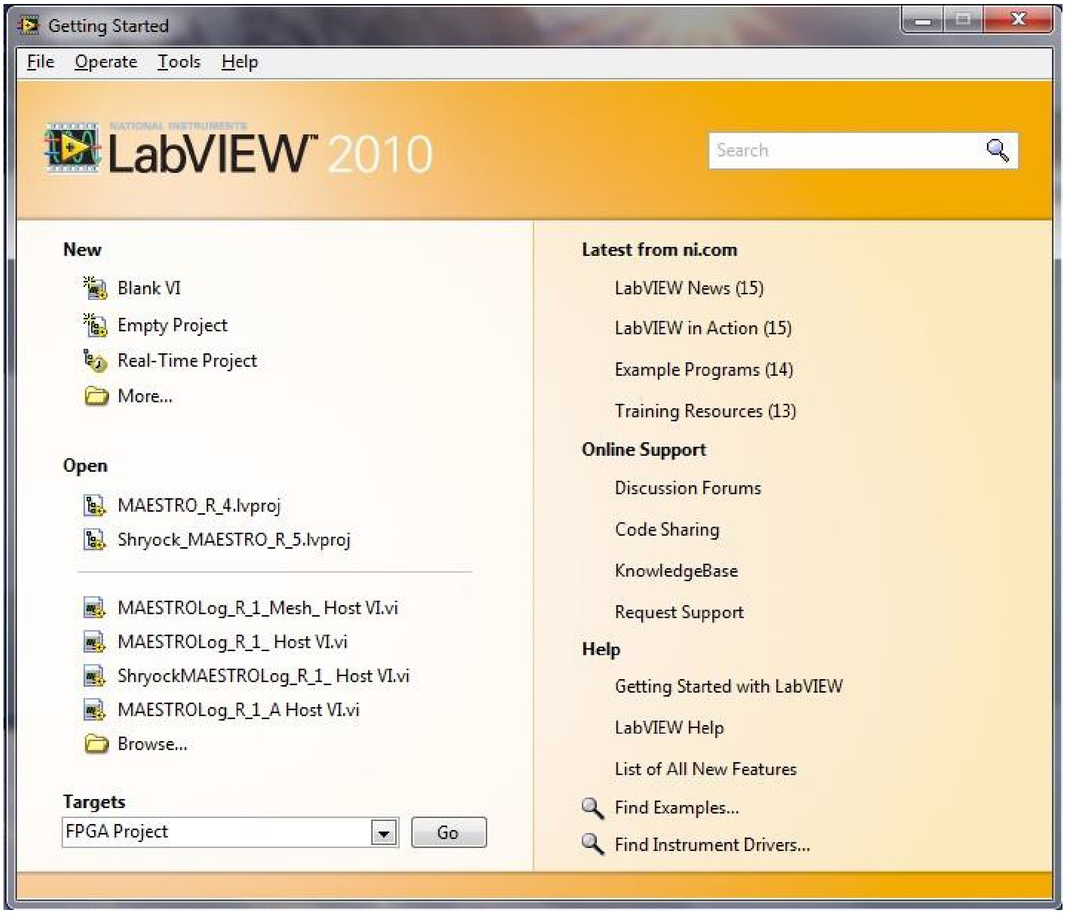
Software

The current system is set to run with a LabVIEW program with a graphical interface that displays real-time data. Additionally, the Measurement and Automation program serves as a system-check and vitals of the system.

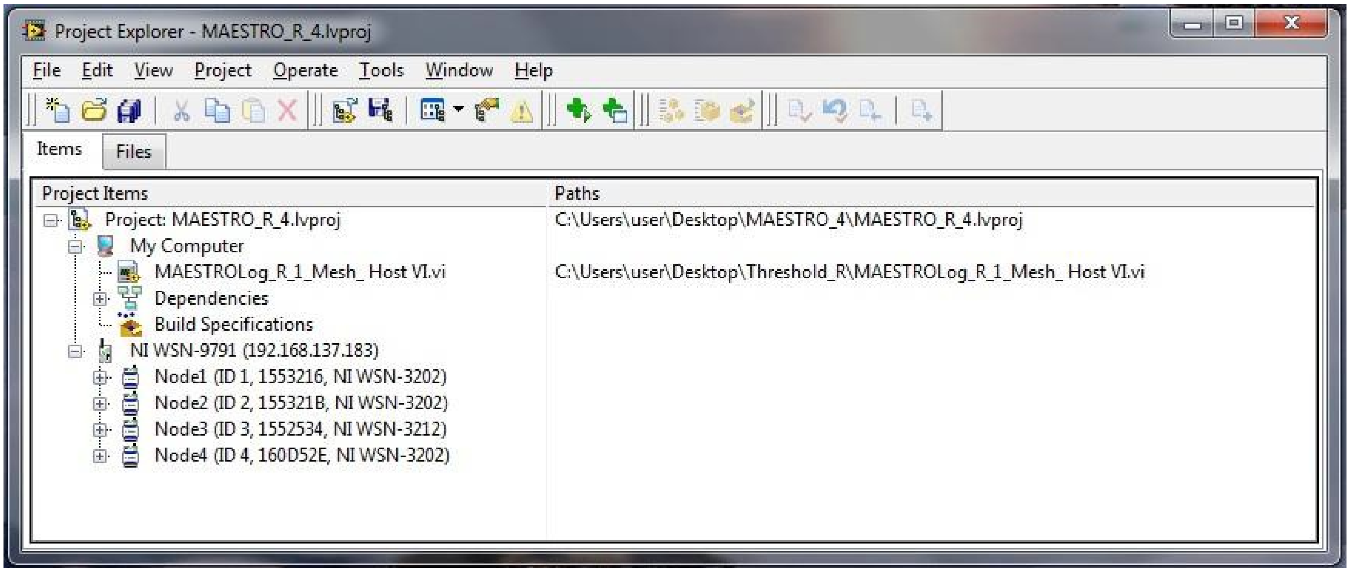
Operation of Software:

- LabVIEW

To enter LabVIEW, click on icon on desktop. Once LabVIEW has loaded, select the project you would like to load. (i.e. MAESTRO_R_4.lvproj)

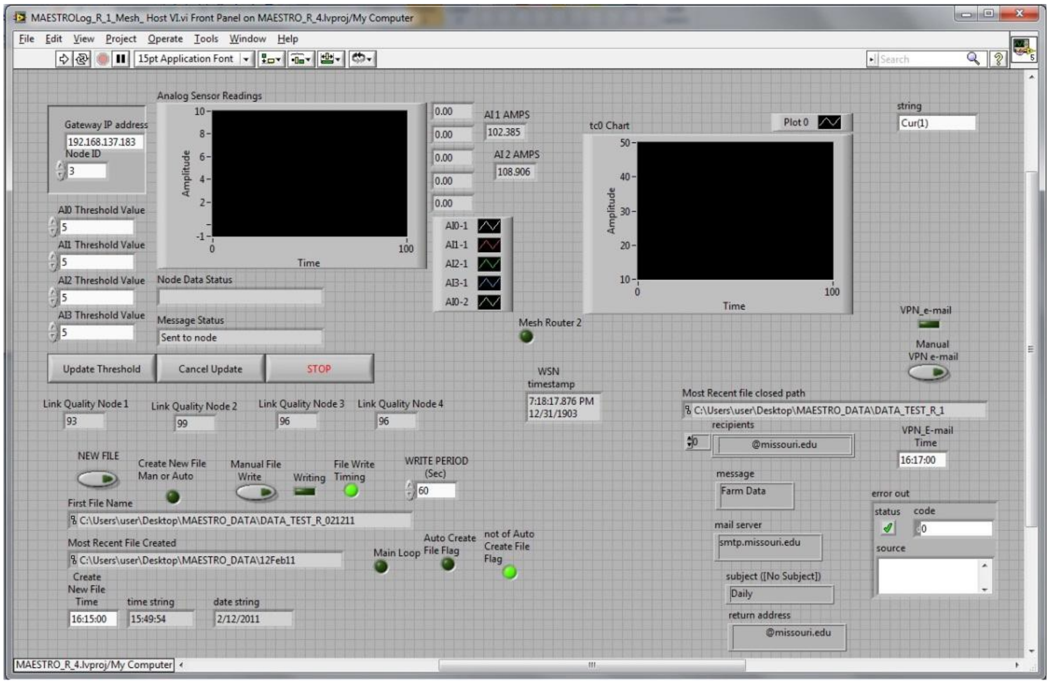


From project explorer, double click on project “host”, (i.e. MAESTRO_R_4_host.lvproj), to open graphic user interface



Project Items	Paths
Project: MAESTRO_R_4.lvproj	C:\Users\user\Desktop\MAESTRO_4\MAESTRO_R_4.lvproj
My Computer	
MAESTROLog_R_1_Mesh_ Host VI.vi	C:\Users\user\Desktop\Threshold_R\MAESTROLog_R_1_Mesh_ Host VI.vi
Dependencies	
Build Specifications	
NI WSN-9791 (192.168.137.183)	
Node1 (ID 1, 1553216, NI WSN-3202)	
Node2 (ID 2, 155321B, NI WSN-3202)	
Node3 (ID 3, 1552534, NI WSN-3212)	
Node4 (ID 4, 160D52E, NI WSN-3202)	

From graphic user interface, select the arrow pointing to the right in the upper left hand corner



Gateway IP address
192.168.137.183
Node ID
3

AI0 Threshold Value
5
AI1 Threshold Value
5
AI2 Threshold Value
5
AI3 Threshold Value
5

Node Data Status

Message Status
Sent to node

0.00
0.00
0.00
0.00
0.00

AI 1 AMPS
102.385
AI 2 AMPS
108.906

string
Cur(1)

Link Quality Node 1
93
Link Quality Node 2
99
Link Quality Node 3
96
Link Quality Node 4
96

WSN timestamp
7:18:17.876 PM
12/31/1903

WRITE PERIOD (Sec)
60

First File Name
C:\Users\user\Desktop\MAESTRO_DATA\DATA_TEST_R_021211

Most Recent File Created
C:\Users\user\Desktop\MAESTRO_DATA\12Feb11

Create New File Time
16:15:00
time string
15:49:54
date string
2/12/2011

Most Recent file closed path
C:\Users\user\Desktop\MAESTRO_DATA\DATA_TEST_R_1

recipients
0
@missouri.edu

VPN_E-mail Time
16:17:00

message
Farm Data

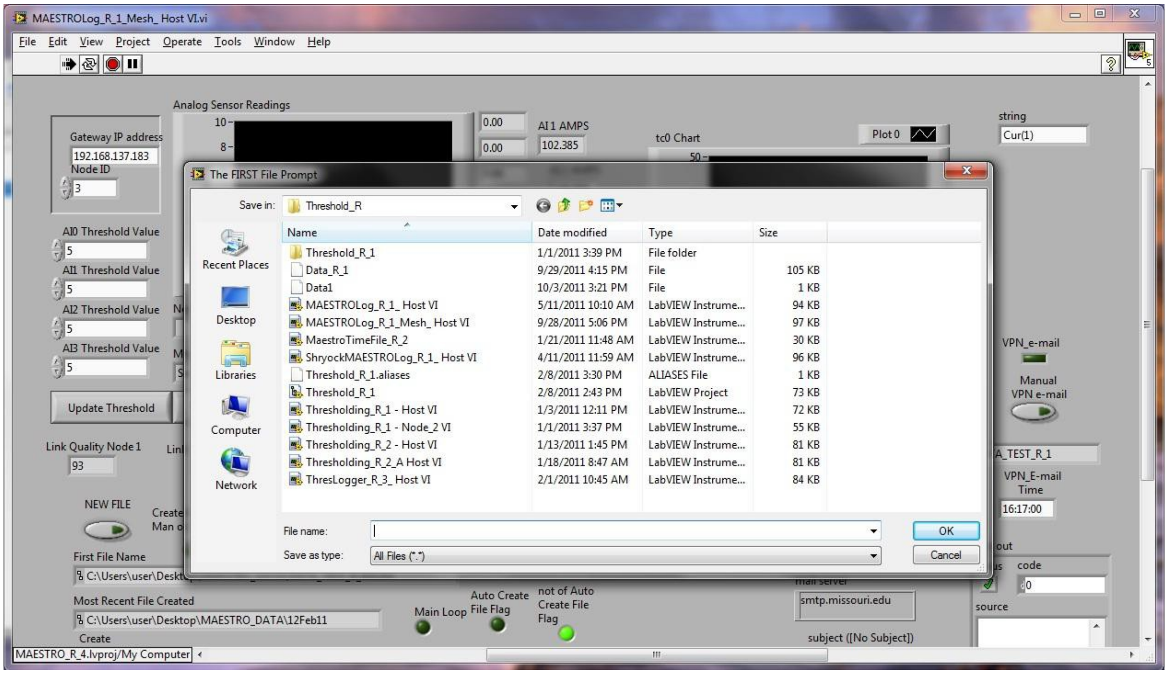
mail server
smtp.missouri.edu

subject ([No Subject])
Daily

return address
@missouri.edu

error out
status
✓
code
0
source

In windows explorer, select or create file to save data to.



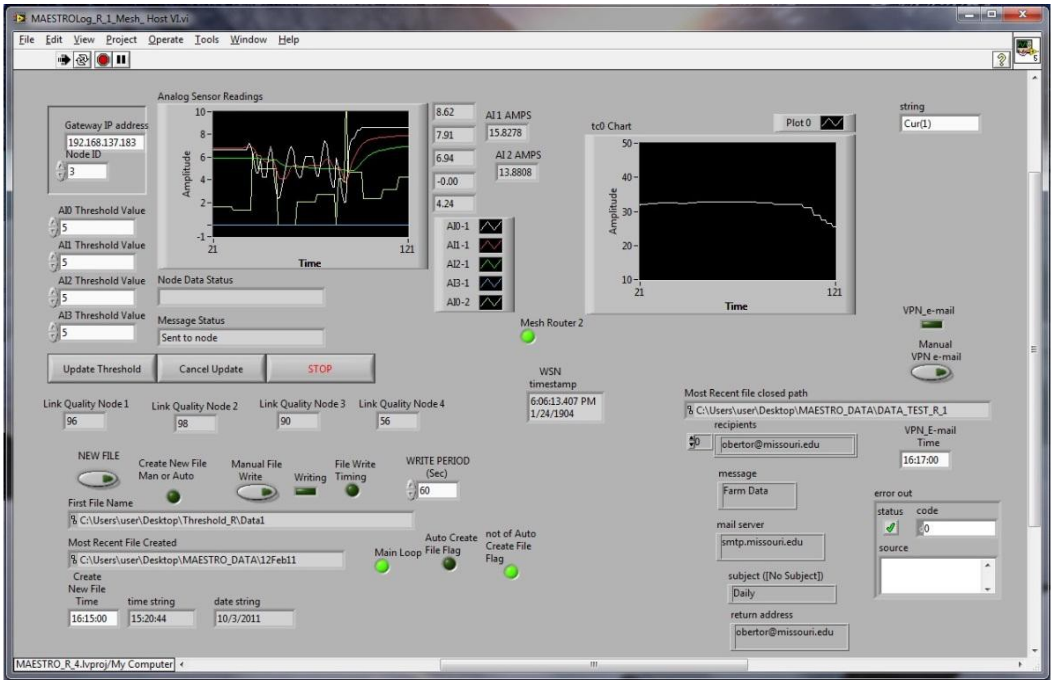
Gateway IP address: 192.168.137.183
Node ID: 3
AI0 Threshold Value: 5
AI1 Threshold Value: 5
AI2 Threshold Value: 5
AI3 Threshold Value: 5
AI1 AMPS: 102.385
string: Cur(1)
Link Quality Node 1: 93
VPN_E-mail Time: 16:17:00
First File Name: C:\Users\user\Deskt
Most Recent File Created: C:\Users\user\Desktop\MAESTRO_DATA\12Feb11
mail server: smtp.missouri.edu
code: 0

Save in: Threshold_R

Name	Date modified	Type	Size
Threshold_R_1	1/1/2011 3:39 PM	File folder	
Data_R_1	9/29/2011 4:15 PM	File	105 KB
Data1	10/3/2011 3:21 PM	File	1 KB
MAESTROLog_R_1_ Host VI	5/11/2011 10:10 AM	LabVIEW Instrume...	94 KB
MAESTROLog_R_1_Mesh_ Host VI	9/28/2011 5:06 PM	LabVIEW Instrume...	97 KB
MaestroTimeFile_R_2	1/21/2011 11:48 AM	LabVIEW Instrume...	30 KB
ShryockMAESTROLog_R_1_ Host VI	4/11/2011 11:59 AM	LabVIEW Instrume...	96 KB
Threshold_R_1.aliases	2/8/2011 3:30 PM	ALIASES File	1 KB
Threshold_R_1	2/8/2011 2:43 PM	LabVIEW Project	73 KB
Thresholding_R_1 - Host VI	1/3/2011 12:11 PM	LabVIEW Instrume...	72 KB
Thresholding_R_1 - Node_2 VI	1/1/2011 3:37 PM	LabVIEW Instrume...	55 KB
Thresholding_R_2 - Host VI	1/13/2011 1:45 PM	LabVIEW Instrume...	81 KB
Thresholding_R_2_A Host VI	1/18/2011 8:47 AM	LabVIEW Instrume...	81 KB
ThresLogger_R_3_ Host VI	2/1/2011 10:45 AM	LabVIEW Instrume...	84 KB

File name:
Save as type: All Files (*.*)

Program then begins to run, while the progress is shown on the plots. Voltage and temperature are displayed, respectively. Below is an example displaying the system.

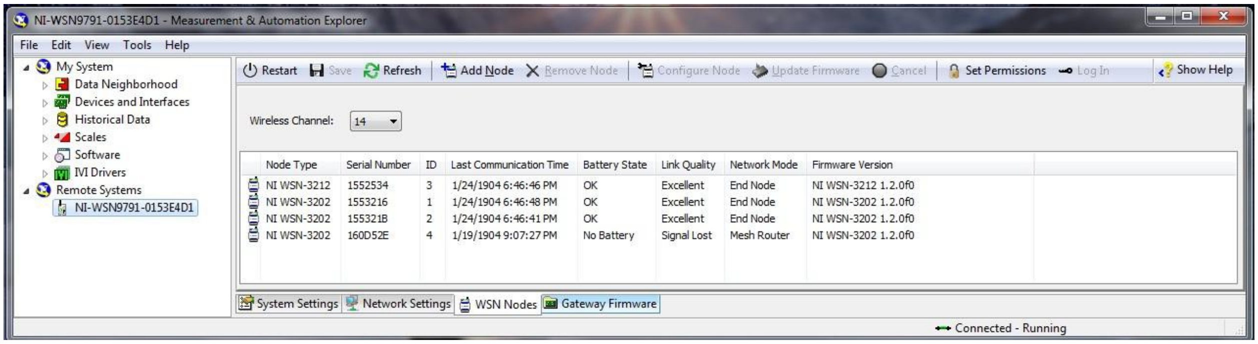


Gateway IP address: 192.168.137.183
Node ID: 3
AI0 Threshold Value: 5
AI1 Threshold Value: 5
AI2 Threshold Value: 5
AI3 Threshold Value: 5
8.62
7.91
6.94
-0.00
4.24
AI1 AMPS: 15.8278
AI2 AMPS: 13.8808
string: Cur(1)
Node Data Status:
Message Status: Sent to node
Link Quality Node 1: 96
Link Quality Node 2: 98
Link Quality Node 3: 90
Link Quality Node 4: 56
WSN timestamp: 6:06:13.407 PM 1/24/1904
WRITE PERIOD (Sec): 60
First File Name: C:\Users\user\Desktop\Threshold_R\Data1
Most Recent File Created: C:\Users\user\Desktop\MAESTRO_DATA\12Feb11
Create New File Time: 16:15:00
time string: 15:20:44
date string: 10/3/2011
Most Recent file closed path: C:\Users\user\Desktop\MAESTRO_DATA\DATA_TEST_R_1
recipients: 0 obertor@missouri.edu
VPN_E-mail Time: 16:17:00
message: Farm Data
mail server: smtp.missouri.edu
subject ([No Subject]): Daily
return address: obertor@missouri.edu
error out: status ✓ code 0
source:

- ➢ Measurement & Automation

To enter Measurement & Automation, click on icon on desktop. Once Measurements and Automation has loaded, navigate to "remote systems" of tree diagram.

- Displays vitals in nodes
- May connect/disconnect nodes
- Configure operation of nodes



Wireless Channel: 14

Node Type	Serial Number	ID	Last Communication Time	Battery State	Link Quality	Network Mode	Firmware Version
NI WSN-3212	1552534	3	1/24/1904 6:46:46 PM	OK	Excellent	End Node	NI WSN-3212 1.2.0f0
NI WSN-3202	1553216	1	1/24/1904 6:46:48 PM	OK	Excellent	End Node	NI WSN-3202 1.2.0f0
NI WSN-3202	155321B	2	1/24/1904 6:46:41 PM	OK	Excellent	End Node	NI WSN-3202 1.2.0f0
NI WSN-3202	160D52E	4	1/19/1904 9:07:27 PM	No Battery	Signal Lost	Mesh Router	NI WSN-3202 1.2.0f0

Suggested Tools & Equipment

Below is a list of tools and equipment that is highly recommended to be used and maintained for projects and on-site installation of the monitoring equipment.

- Screwdriver
- Wire stripers
- Voltmeter
- Thermal couple wire
- Beldon 8442 wire
- Ethernet cable
- Antenna
- Light meter
- Soldering Iron and Solder

Good Practices & Ethics

- Maintain the highest level of professionalism as if you were a representative for your organization/workplace.
- Conduct yourself with honesty and integrity at all times toward all people.
- Respect all people, property, equipment, etc. in the highest manner.
- Listen and allow people to give information without interrupting them.
- Collect information about the machinery/system(s) regarding operation, safety, etc. beforehand.
- Allow at least five business days prior for scheduling visits.
- On visits, always ask for permission to photograph or document information.
- Maintain the confidentiality of the client along with the data, documentation, etc. unless given permission to do so.

Installation

Installation is another key role in the success for your project and this section is provided to serve as guidelines for the installation process. When installing the gateway, node(s), sensors, etc., it is important to install it properly as well as safely. When dealing with any kind of mechanical or electrical systems, it is essential that they are completely powered off prior to installing measurement equipment.

Gateway:

The gateway should be installed in a location where it has a constant power supply via a standard electrical outlet as well as somewhere it will not be tampered with. Additionally, the gateway should not be exposed to the elements (water, wind, fire, etc.) as this may damage the device. The gateway may also be mounted in an encasement provided by National Instruments that be mounted outside. The encasement provides a waterproof, tamper-free and rigid enclosure solution.

Nodes:

The installation location of the nodes is all particular of the project you are working on. However, they must be installed where they are in range where it can communicate with the gateway. If the node is out of range of the gateway, a mesh router configuration may be implemented to increase the range of communication. The node needs to be placed in a location where it is not exposed to the elements, just as the gateway. An enclosure is provided by National Instruments that offers a waterproof, tamper-free and rigid solution if it needs to be mounted outside. Additionally, the nodes should be placed where it will not affect normal operations of daily tasks with the property owner.

Sensors:

Current Sensor:

Current sensors are usually placed in the electrical panel of the building you are monitoring. It is important to follow the guidelines as mention in the “Safety” portion of this manual when installing the sensor in the panel. The current sensor has two sides that must be noted for installing it properly: positive terminal and negative terminal. Depending on the direction of the current, it is recommended to record only the positive value of the current. If the sensor were installed backwards, you would receive the same values except they would be negative.

To install the sensor, turn the latch counter-clock wise (with the text and logo upright) and open the lever. Place the sensor onto the wire, close the lever and rotate the latch clockwise. Cut the appropriate length of wire, strip the ends and insert the wire into the desired input of the node. The sensor should be placed somewhere it will not be in contact with any kind of liquid or tampered with. Upon completion of installation, verify initial results as noted in the “Field Calibration” section prior to leaving.

Anemometer:

The anemometers are placed where ever you would like to take measurements of air flow. The turbine part of the anemometer should be mounted where you would like sample the air flow. Generally, this will be mounted on a telescoping stand where different heights of air flow measurements can be taken. The handheld part of the anemometer should be placed somewhere it will not be in contact with any kind of liquid or tampered with. From the analog output wires of the anemometer, insert the respective wires into the desired input terminals of the node (i.e. positive wire inserted into positive terminal). Upon completion of installation, verify initial results as noted in the "Field Calibration" section prior to leaving.

Thermocouple:

Thermocouple wire can be placed where you would like to take temperature measurements. The wire is rigid enough where you can bend the wire and maintain a shape or use it to hold it self-upright. To set up the thermocouple wire, strip the ends of the wire and either twist tie the ends or solder them together. Cut the appropriate length of wire, strip the ends and insert the wire into the desired input of the node. It is important that the respective wires are inserted in the terminals of the node (i.e. positive wire inserted into positive terminal). Additionally, it is important for the sensor to be free from liquid contact and tamper. Upon completion of installation, verify initial results as noted in the "Field Calibration" section prior to leaving.

Humidity Sensor:

The humidity sensor is placed along with the anemometer and mounted by means of either hanging from an overhead pipe or screw hardware. The sensor should be placed at the same height of the turbine part of the anemometer. Cut the appropriate length of wire, strip the ends and insert the wire into the desired input of the node. It is important that the respective wires are inserted in the terminals of the node (i.e. positive wire inserted into positive terminal). Additionally, it is important for the sensor to be free from liquid contact and tamper. Upon completion of installation, verify initial results as noted in the "Field Calibration" section prior to leaving.

Light Sensor:

The light sensor can be placed where you would like to take measurements of the illumination or intensity of the light source. The optical part of the sensor should be placed in the area and direction of the light source. It is recommended having the sensor placed on a flat surface such as a shelf or table. To operate the sensor, remove the cover from the optical part. Then switch the sensor to the desired settings of your needs. The higher the desiredFrom the digital output of the sensor, insert wire that has already had the insulation cut away into the sensor. Cut the appropriate length of wire, strip the ends and insert the wire into the desired input of the node. It is important that the respective wires are inserted in the terminals of the node (i.e. positive wire inserted into positive terminal). Additionally, it is important for the digital readout display to be free from liquid contact and tamper. Upon completion of installation, verify initial results as noted in the “Field Calibration” section prior to leaving.

Field Calibration

Verifying the data is an essential part of the project and it is recommended to bring additional tools to verify results of the monitoring system:

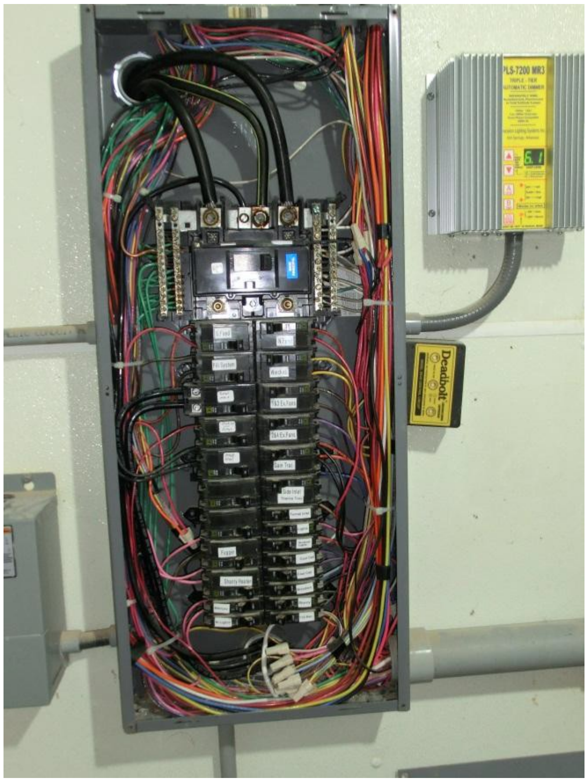
- Thermocouple
A simple thermometer can be used to verify the temperature measured by the thermocouple node.
- Humidity
A hygrometer can be used to verify that the humidly measurement taken by the humidity sensor node.
- Electrical (voltage, current, resistance, etc)
A voltmeter measures the current, voltage, or resistance difference between two points and verify the reading measured by the node.
- Air Flow
Before completing the setup of the energy monitoring system, measure the voltage produced by the anemometer with a voltmeter to ensure that the anemometer is functioning and outputting reasonable values.

Safety

Safety is above all when installing systems and none of these guidelines should be ignored. Additionally, abide by all laws and/or safety regulations set by local, state, or national government.

- Electrical

- Do not work with electrical wiring unless trained and educated to do so.
- Use insulating gloves when working with electrical wiring
- Be observant of the initial and final condition of all wiring. Check to make sure that nothing has been incorrectly modified or disturbed before finishing work
- Be aware of conditions required for some distribution systems, such as dust-free environments for circuit breakers while working
- Abide to all warnings and instructions as provided by the manufacturer
- If necessary, consult a electrician or technician for technical assistance



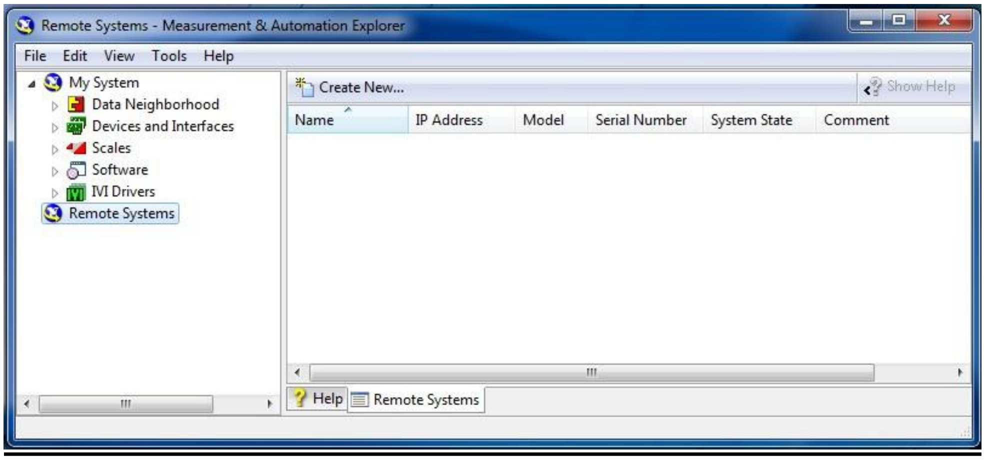
- Mechanical

- Do not enter foreign objects into machinery unless for measurementation and does not interfere with normal operation
- Use proper equipment as necessary such as gloves while machinery may be hot
- Ensure the device is completely powered down prior to modification
- Never remove a safety device unless for maintenance
- Abide to all warnings and instructions as provided by the manufacturer

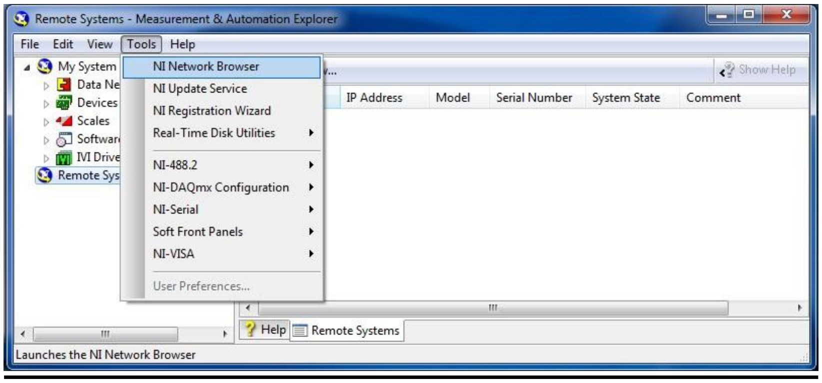
- If necessary, consult a technician for technical assistance

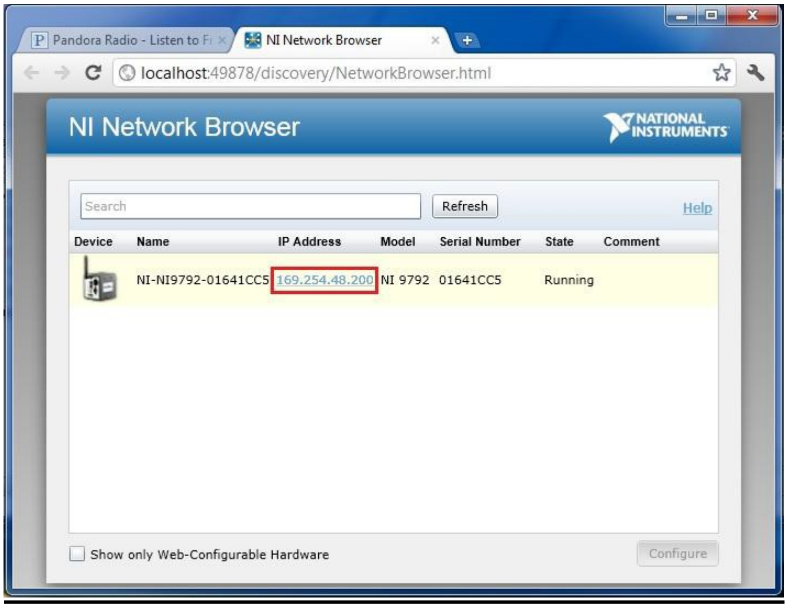
Adding/Configuring Gateway through Measurement and Automation

Open Measurement & Automation and ensure you have powered on your Gateway. Your gateway should have a reliable source of power and will need to be on at all times for data collection. Once power on, select "Remote Systems" from the left side of the pane. The figure below displays what a new system being created.



To add your gateway to Measurement & Automation, you need to create a connection via Ethernet from the gateway to an open Ethernet port located on your host computer. Without this connection, you cannot successfully add your gateway to Measurement & Automation. Once you have created a connection through the Ethernet, we must then look up the corresponding IP address associated with the gateway. To do this, we need to navigate to the top of Measurement & Automation to the "Tools" drop box. You will them navigate to "NI Network Brower". You must have an internet browser such as Internet Explorer, Mozilla Firefox, or Google Chrome to do this process. The figures below show the steps to navigate to "NI Network Browser" and what "NI Network Browser should look like with your gateway, respectively.

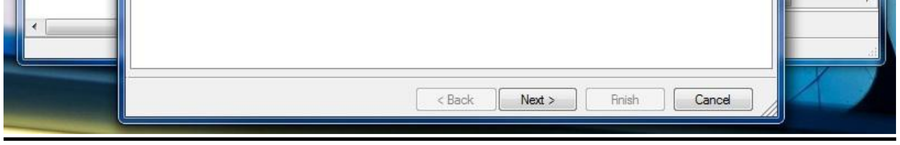




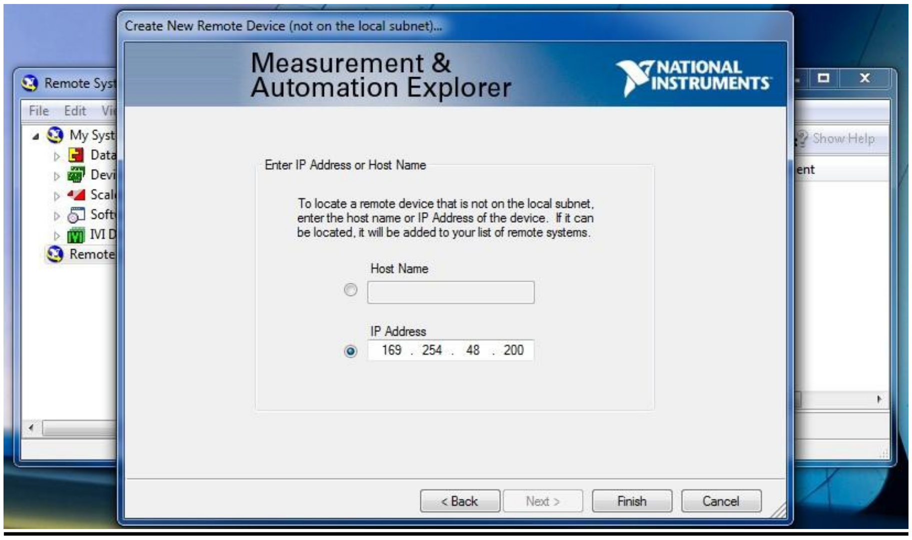
Device	Name	IP Address	Model	Serial Number	State	Comment
	NI-NI9792-01641CC5	169.254.48.200	NI 9792	01641CC5	Running	

Once navigated to “NI Network Browser”, you will need to write down all of the following credentials shown above in the figure with the exception of the “State”. The most important credential is the IP address associated with the gateway. It is essential to have the exact address of the gateway, or the connection will be unsuccessful.

After this is completed, you will then navigate back to Measurement & Automation. You will then right-click on “Remote Systems” on the left pane of the window and select “Create New”. The figure below displays what the following screen will display once completing this step. You will then select on “Remote Devices (not on the local subnet)”, which is also displayed in the figure below.



After completing this step, you will be brought to a window that looks like the figure below with the exception of a blank IP address. Select the option for IP address, and you will enter your IP address of your gateway that you noted earlier in the “NI Network Browser”. Again, it is essential that you input the exact IP address of the gateway or will result in error and/or unsuccessful connection(s). Click on finish to complete the process.



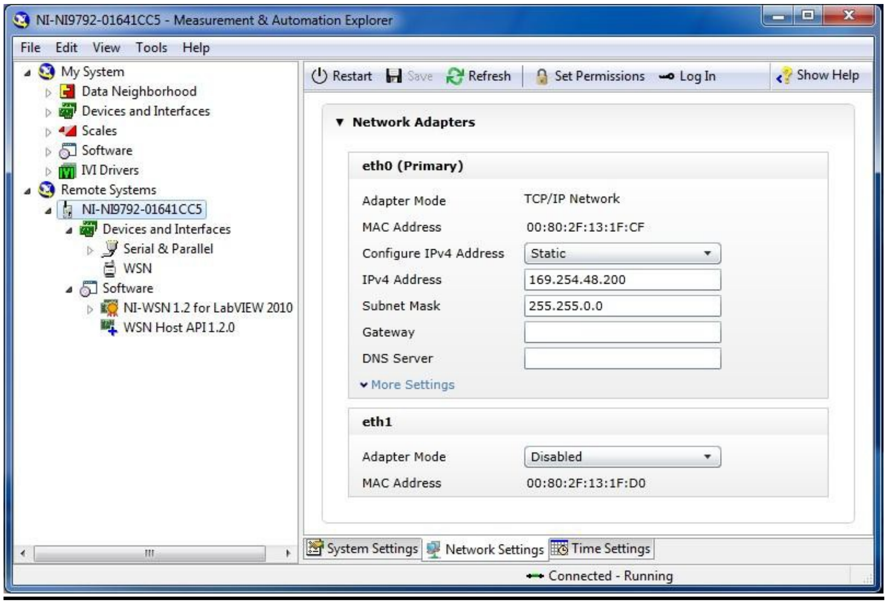
Enter IP Address or Host Name

To locate a remote device that is not on the local subnet, enter the host name or IP Address of the device. If it can be located, it will be added to your list of remote systems.

○ Host Name

● IP Address 169 . 254 . 48 . 200

You will then be brought back to Measurement & Automation with a screen that looks similar to the figure below. This is where you may adjust the settings of the gateway, and focused towards more advanced users. The only change that may be necessary is to ensure the “Configure IPv4 Address” is selected as static. With this selection, the IP address will be consistently the same and will not change with each new connection.



▼ Network Adapters

eth0 (Primary)

Adapter Mode	TCP/IP Network
MAC Address	00:80:2F:13:1F:CF
Configure IPv4 Address	Static
IPv4 Address	169.254.48.200
Subnet Mask	255.255.0.0
Gateway	
DNS Server	

eth1

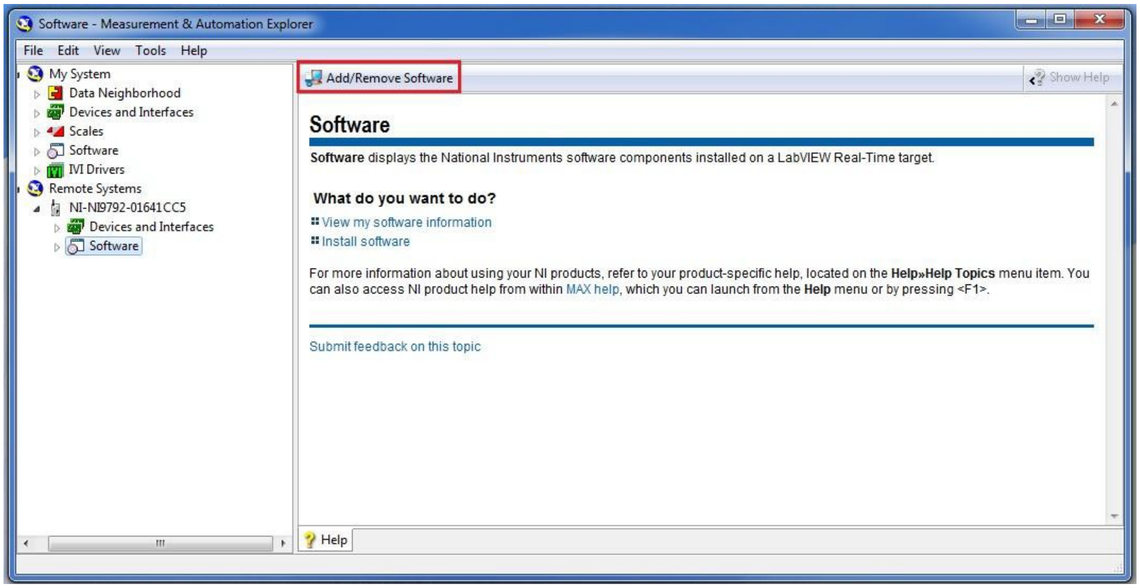
Adapter Mode	Disabled
MAC Address	00:80:2F:13:1F:D0

With completion of these steps, you have successfully added a gateway to Measurement & Automation. The next process will guide you to adding a gateway to your project for data collection.

Adding/Removing Software to Gateway

For the first time use of your gateway, you must first install a number of LabVIEW programs for the system to operate. Once these programs are installed, you will not have to again unless you encounter a major software error (may require reinstallation) or reformat the gateway. To install the software, you must have the core software installed on a host computer to be transferred onto the gateway. A comprehensive list of the software needed on the host is listed at the end of this manual and can be found on the available discs included with the system. Once adding the necessary software on the host, you may now continue with the installation of the programs onto the gateway.

Open Measurement & Automation and navigate through the tree diagram on the left to your already connected gateway. Within the tree diagram of your gateway, navigate to the "software" option. After then, you will see the option of "Add/Remove Software" at the top pane of the right window; click on it. The figure below serves as an example to navigate to the option through Measurement & Automation and highlights the "Add/Remove Software" option.



Software

Software displays the National Instruments software components installed on a LabVIEW Real-Time target.

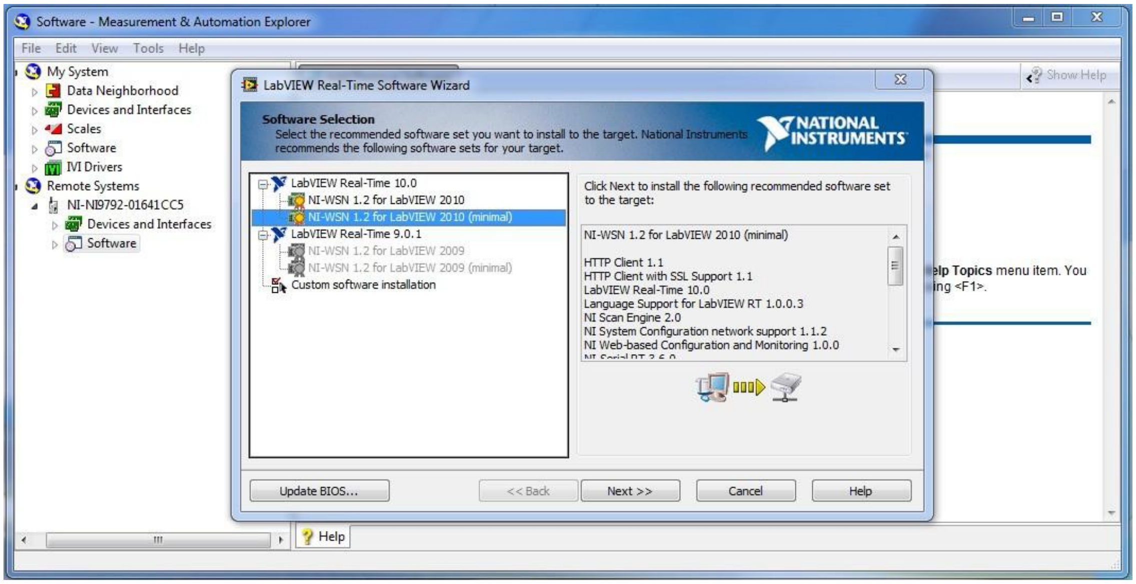
What do you want to do?

- View my software information
- Install software

For more information about using your NI products, refer to your product-specific help, located on the **Help»Help Topics** menu item. You can also access NI product help from within MAX help, which you can launch from the **Help** menu or by pressing <F1>.

Submit feedback on this topic

Once completing this action, you will be brought into a wizard to add the software needed. Depending on your application of the system, any selection for either option is appropriate. However throughout this manual, we will be focusing on using the "NI-WSN 1.2 for LabVIEW (minimal)" and is strongly recommended. After selecting your software package, select 'next' within the wizard and will begin installation of the software on the gateway.



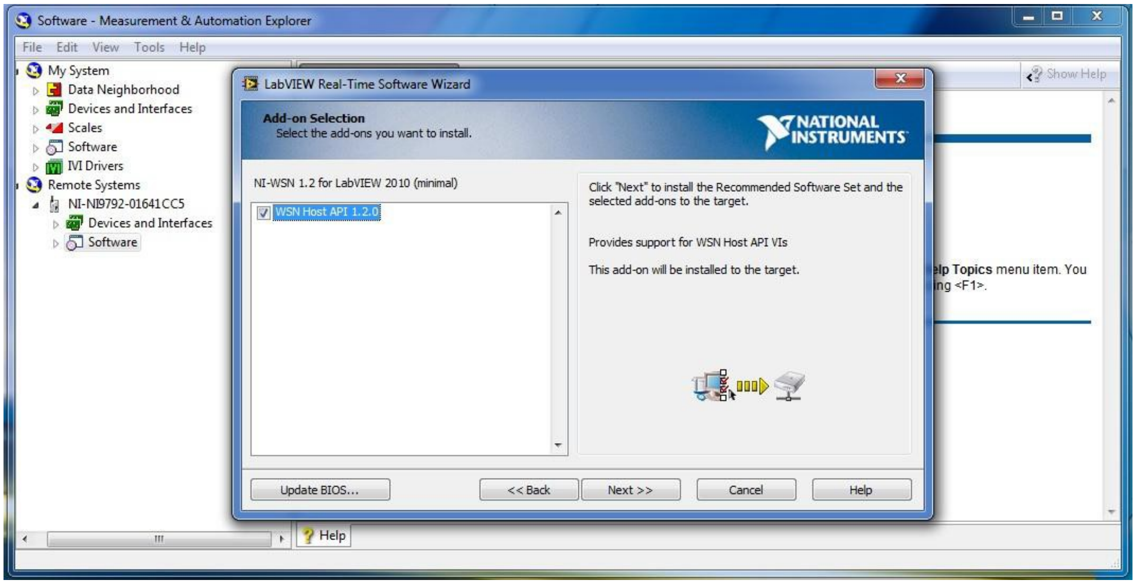
Software Selection
Select the recommended software set you want to install to the target. National Instruments recommends the following software sets for your target.

Click Next to install the following recommended software set to the target:

NI-WSN 1.2 for LabVIEW 2010 (minimal)

HTTP Client 1.1
HTTP Client with SSL Support 1.1
LabVIEW Real-Time 10.0
Language Support for LabVIEW RT 1.0.0.3
NI Scan Engine 2.0
NI System Configuration network support 1.1.2
NI Web-based Configuration and Monitoring 1.0.0

Then you will be asked for the option of adding “optional” software. For this application, “WSN Host API 1.2.0” is required for the success and operation of the system. If you do not have this option, repeat steps of the program installation on the host. To select the option, check the box next to the available add-on and select ‘next’ at the bottom of the wizard.



Add-on Selection
Select the add-ons you want to install.

NI-WSN 1.2 for LabVIEW 2010 (minimal)

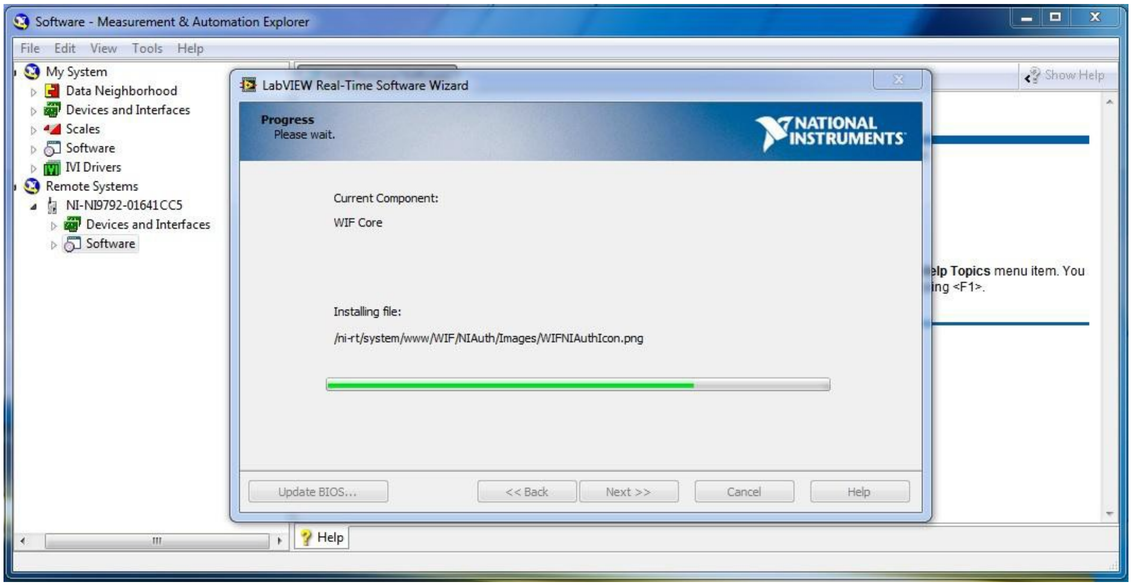
☑ WSN Host API 1.2.0

Click "Next" to install the Recommended Software Set and the selected add-ons to the target.

Provides support for WSN Host API VIs

This add-on will be installed to the target.

After selecting the ‘next’ button, the wizard will finally begin installation of software on the gateway. It is important that you do NOT interrupt the installation or can lead to system crash, software failure, errors, etc. Therefore, do not disconnect the gateway, shutdown/restart your computer, etc. The figure below displays a typical installation.

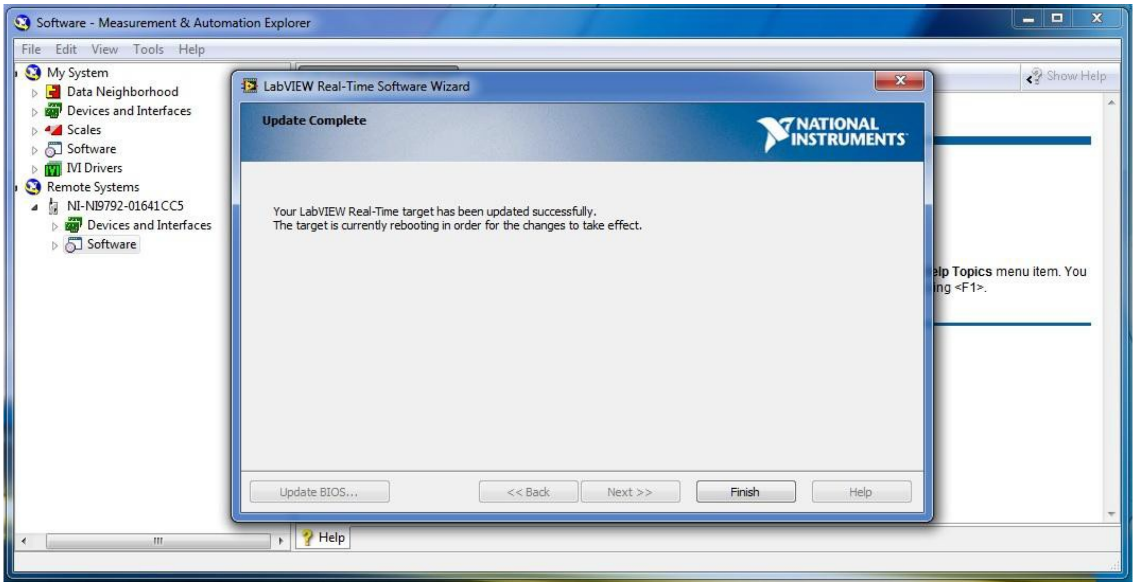


Progress
Please wait.

Current Component:
WIF Core

Installing file:
/ni-rt/system/www/WIF/NIAuth/Images/WIFNIAuthIcon.png

Once the installation is complete, the gateway will need to reboot for the changes to take effect. Again, it is important that you do NOT interrupt the installation or can lead to system crash, software failure, errors, etc. Therefore, do not disconnect the gateway, shutdown/restart your computer, etc. To finish the installation, select the ‘finish’ option at the bottom of the wizard.



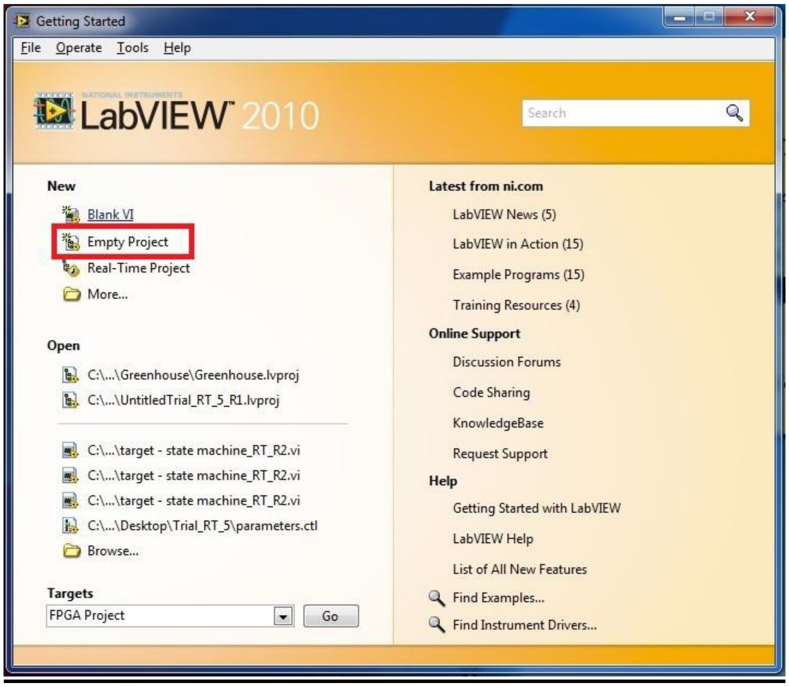
Update Complete

Your LabVIEW Real-Time target has been updated successfully.
The target is currently rebooting in order for the changes to take effect.

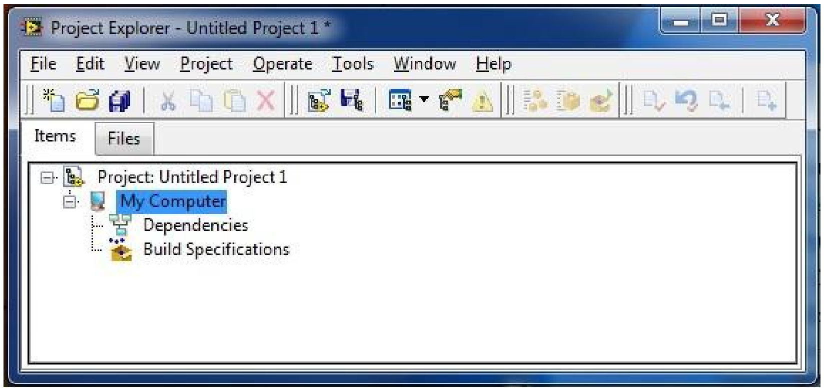
As this step is not required, it is recommended to ensure all the required software has been installed onto the gateway. Open Measurement & Automation, if it is not already open, and navigate through the tree diagram on the left to your already connected gateway. Within the tree diagram of your gateway, navigate to the “software” option. Then ensure each program is installed by comparing the comprehensive list for the “Software Needed on Gateway” list located at the end of this manual.

Creating A New Project (NI-9791)

To begin acquiring data, the first step is to make a new project that will contain the information of the gateway, nodes, and programming of the system. For the NI-9791, the process for creating a new project is a lot simpler compared to the NI-9792. To create a new project, begin by opening LabVIEW. Once loaded, select the "Empty Project" as shown highlighted in the red box in the figure below.

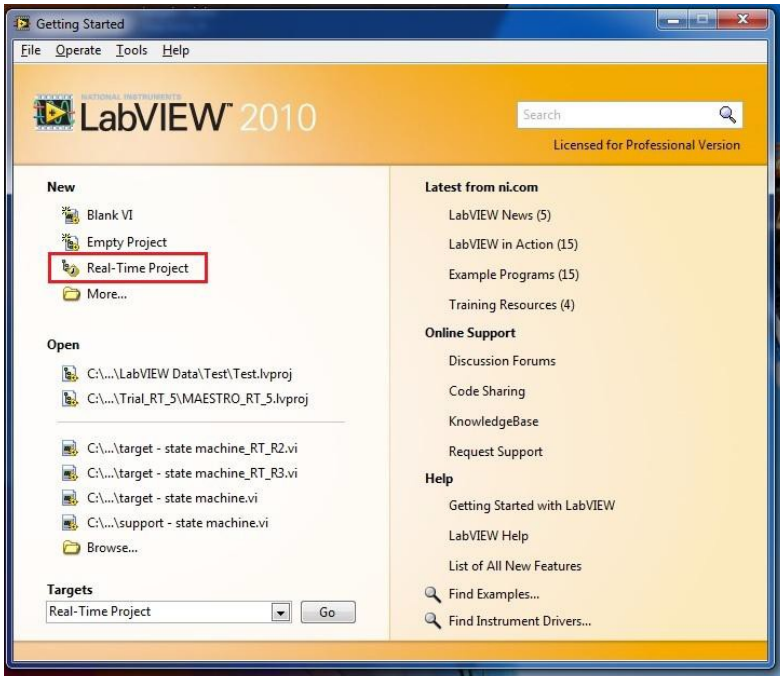


LabVIEW will then begin to create a new project and a new window will appear. From here, you may now begin to add your gateway, nodes, block diagrams, etc.

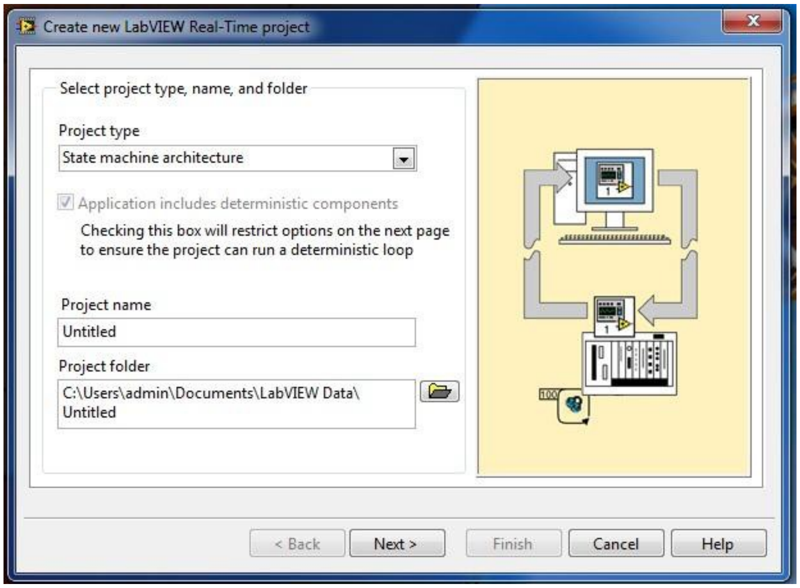


Creating A New Project (NI-9792)

To begin acquiring data, the first step is to make a new project that will contain the information of the gateway, nodes, and programming of the system. To create a project, open LabVIEW and select “Real-Time Project” which is highlighted in the red box as shown below.



A wizard program will then display in a new window which will look similar to the figure below. You will have multiple options to select from such as project type, project name, or project folder. On the project type, select the drop-down menu and select the option “state machine architecture” and then feel free to change the title of your project as you wish. In this example, we will keep the project title as the default title of “Untitled”. Once you have completed these steps, select on the next option below.


Create new LabVIEW Real-Time project

Select project type, name, and folder

Project type: State machine architecture

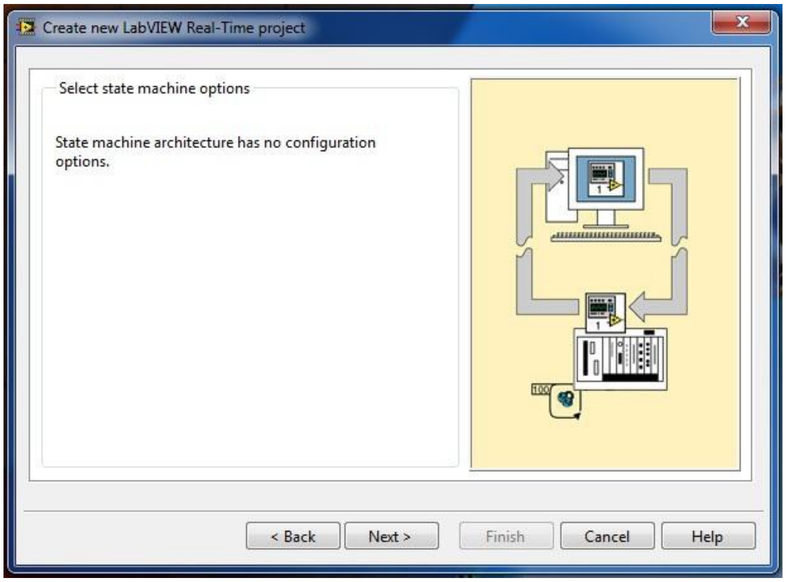
☑ Application includes deterministic components

Checking this box will restrict options on the next page to ensure the project can run a deterministic loop

Project name: Untitled

Project folder: C:\Users\admin\Documents\LabVIEW Data\Untitled

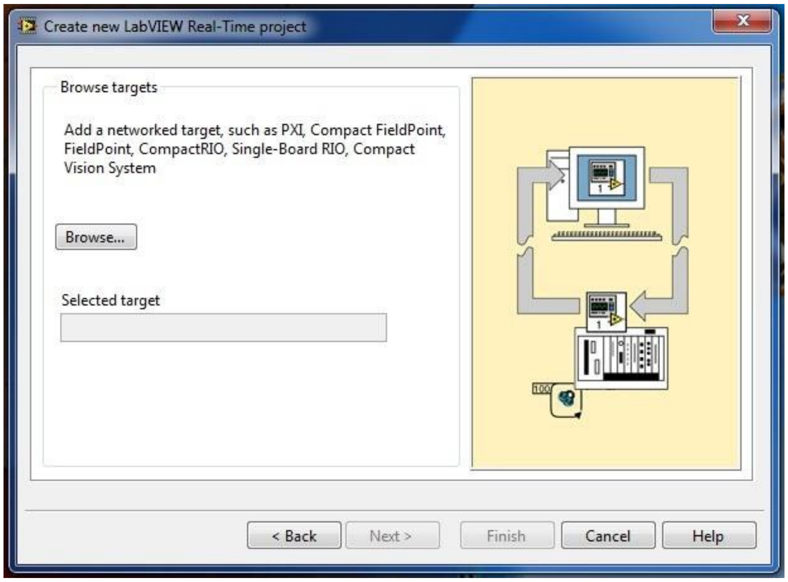
The next step requires no user input, therefore you may just select the next option located at the bottom of the window.



Select state machine options

State machine architecture has no configuration options.

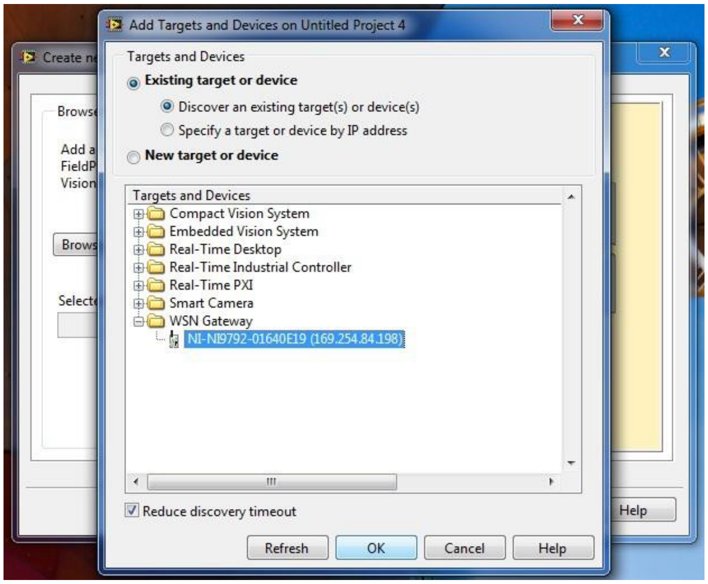
The next step is to direct the target for the real-time project, in this case, the gateway. Select the browse option, and then navigate through the tree diagram of the section of “Existing target or device” and “Discover an existing target(s) or device(s)”. Under the tree diagram explore to WSN Gateway and select your NI-9792 device. Select the “okay” option and then the “next” option to progress to the next step.



Browse targets

Add a networked target, such as PXI, Compact FieldPoint, FieldPoint, CompactRIO, Single-Board RIO, Compact Vision System

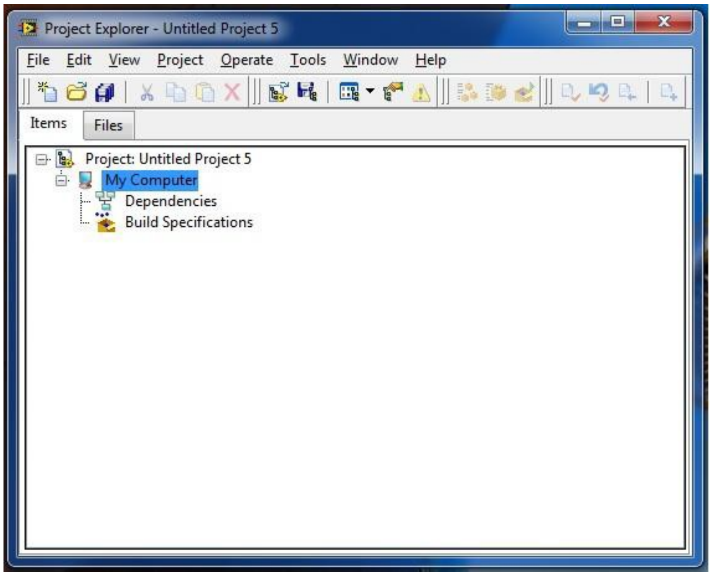
Selected target

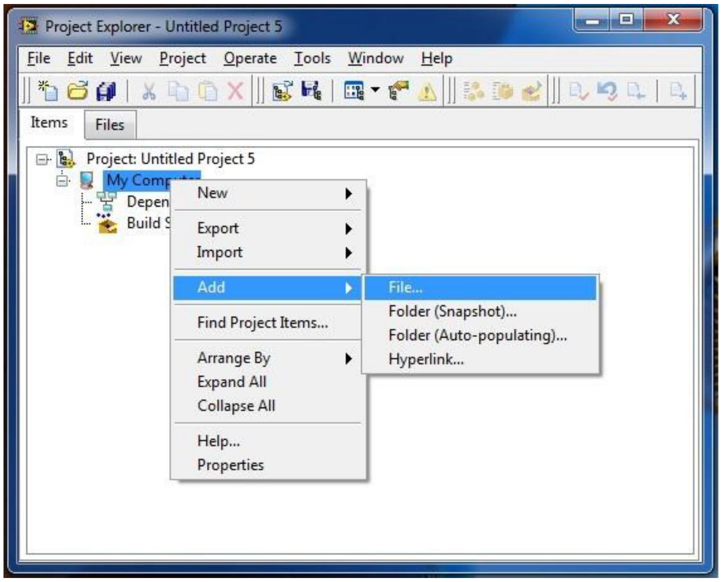


Once completing this step, a window will display all the programs that will go into real-time project as well as information of the gateway. To complete the real-time project, select "finish" and the real-time application will be applied to the host and gateway.

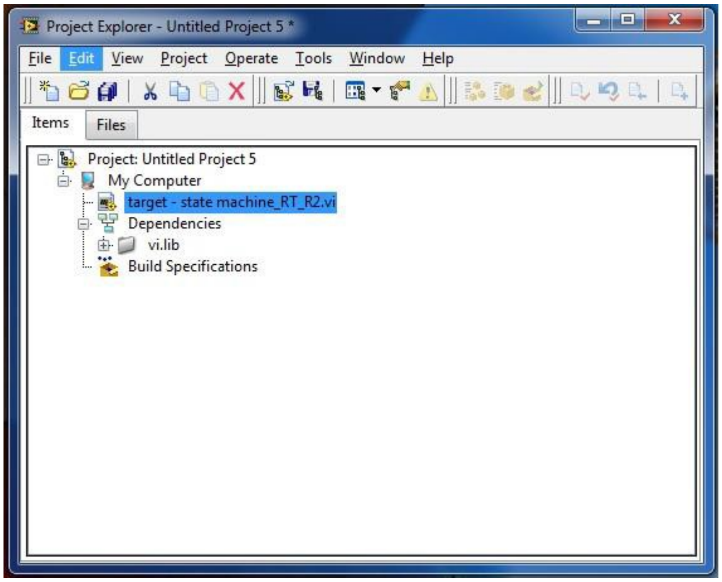
Adding Files/Folders to Project Explorer

Adding specific files or folders is a necessary step if wanting to add previous programs to the gateway or transferring programs from one computer to another. To add files/folders, open LabVIEW and the project you would like to add files to. Once the project explorer of the project is open, right click on "My Computer" and navigate through to Add > File.



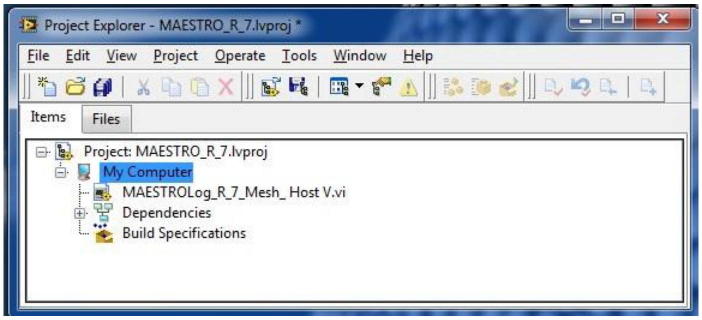


A new window will open which will be the directory of the entire computer. For convenience, it is recommended to save everything to the desktop for ease of access. Once finding the location of the file, click on the file and select "Open". In this example, we be adding the file "target – state machine_RT_R2.vi" to the project "Untitled Project 5". After selecting the "open" option, the file will be then added under the "My Computer" section of the project explorer.

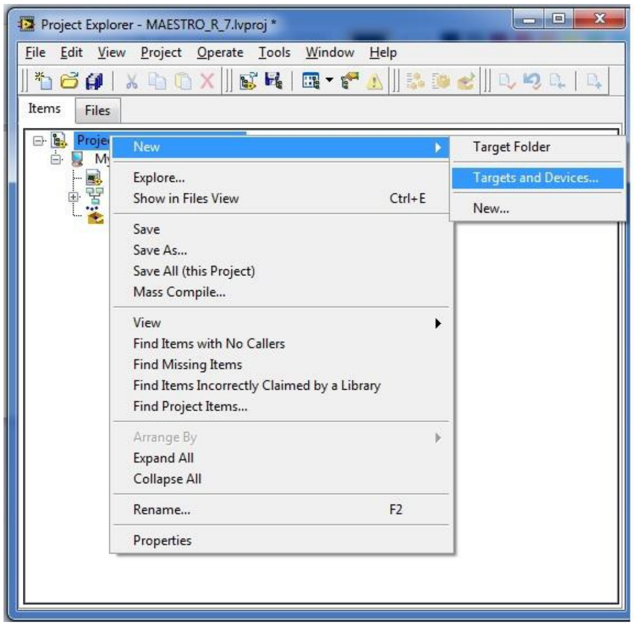


Adding/Configuring Gateway through Project Folder in LabVIEW

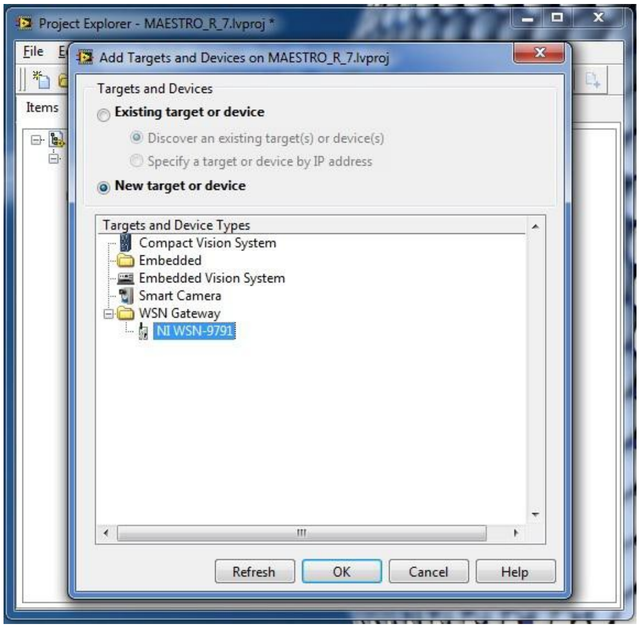
Begin with opening LabVIEW along with your project explorer that contains your project. The figure below displays a sample of a project with no previously added gateway, nodes, etc.



Once you have executed the following step, right click on project within the project explorer, navigate to New > Targets and Devices. This is where we will actually add the gateway to the project. The figure below shows as an example to navigate through the process.



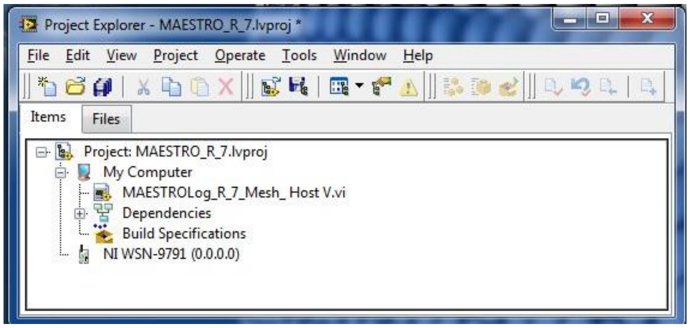
A new window will display with the options of “Existing target or device” or “New target or device”. Since this is a new device, we will be selecting the “New target or device”. You will have several options, but the only one we are interested in is the “WSN Gateway” option. Click on “WSN Gateway”, and the folder will expand and display all the available gateways registered in Measurement & Automation. Select your gateway, and then complete the action my clicking the okay option at the bottom of the window. The figure below is to serve as an example of navigating through the steps.



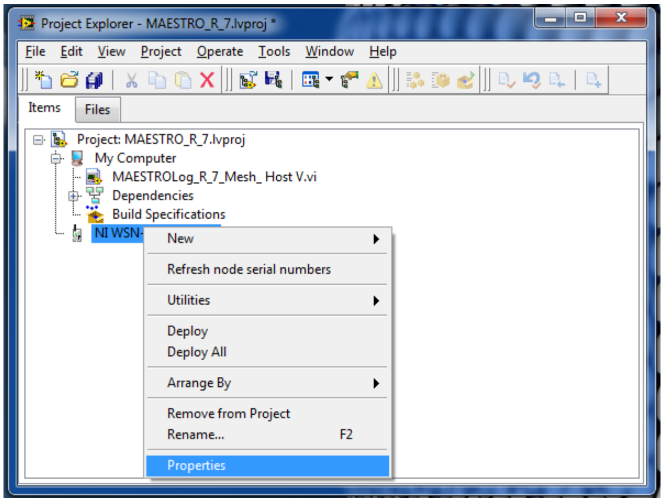
Targets and Devices
○ Existing target or device
● Discover an existing target(s) or device(s)
○ Specify a target or device by IP address
● New target or device

Targets and Device Types
- Compact Vision System
- Embedded
- Embedded Vision System
- Smart Camera
- WSN Gateway
  - NI WSN-9791

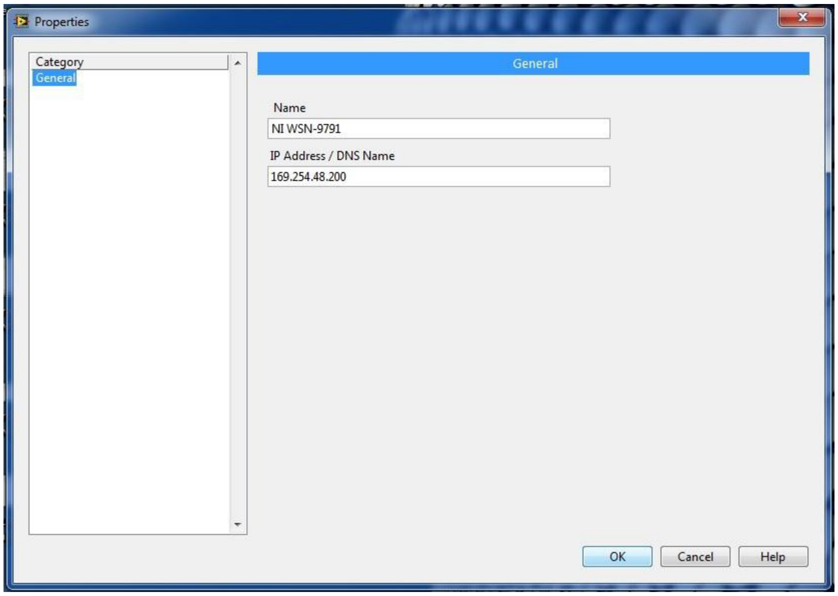
If you have completed the steps properly, you will be directed to a window that looks similar to the figure below. If not, please redirect back to the beginning of the section and repeat the steps.



With the gateway now added to the project for data collection, we will now need to configure the gateway through LabVIEW. To do so, find the gateway within your project explorer and right click on it. You will be given several options and need to navigate to the “properties” option. The figure below displays the available options of the gateway’s configuration.



After selecting the properties option, you will be displayed a window that looks similar to the figure below. You may change the name of the gateway at your discretion, but it is recommended to maintain how it is currently defaulted. However, you must input the IP address of the gateway that you noted of in the “NI Network Browser” or you may view it again in Measurement & Automation. Once inputting the correct IP address, select the OK option at the bottom of the window. Completing this action has successfully added the gateway to your project. It is recommended to hit “ctrl” and “s” on your keyboard simultaneously within the project explorer to save any changes made.



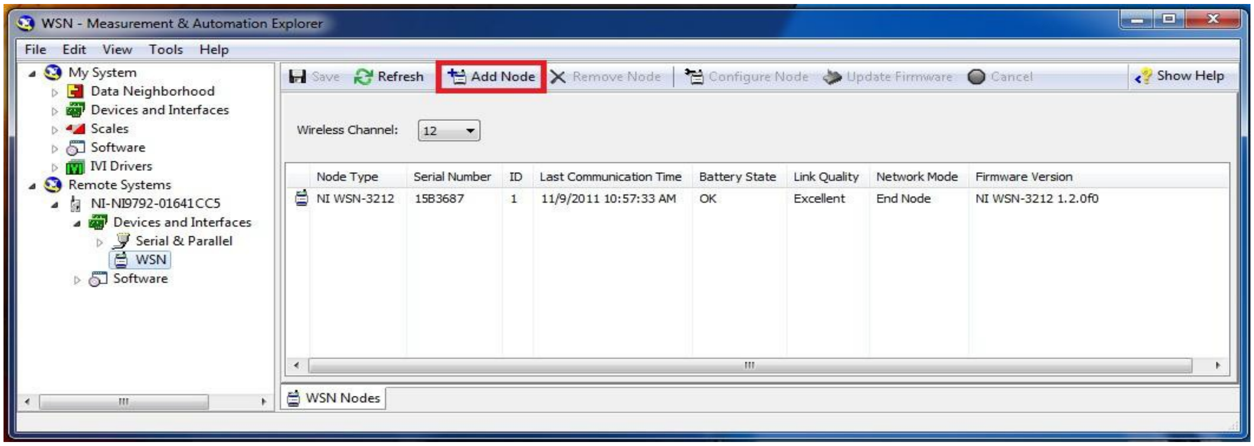
Name
NI WSN-9791

IP Address / DNS Name
169.254.48.200

Adding Nodes to Gateway through Measurement and Automation

It is ideal to have more than one node on a system to measure different properties such as temperature, voltage, moisture, etc. This section will provide detail on how to add or configure your nodes in such a way to your situation.

Open Measurement & Automation and connect to your Gateway. Once connected, select WSN from under the tree diagram. There you will have several options available as displayed below. In this case, we are interested in adding a node so we would select “add node”, which is also highlighted in the figure below.

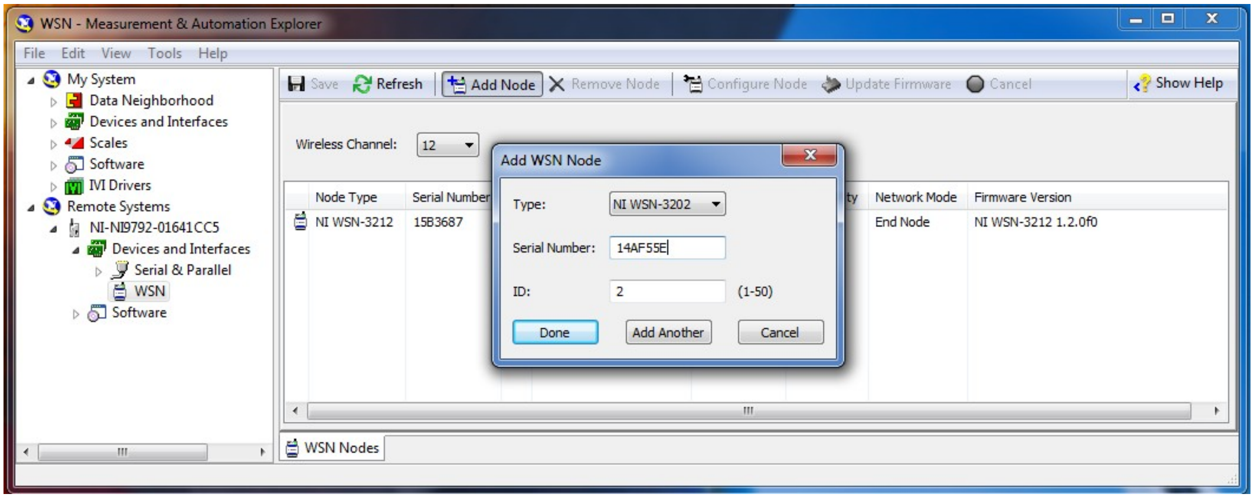


Wireless Channel: 12

Node Type	Serial Number	ID	Last Communication Time	Battery State	Link Quality	Network Mode	Firmware Version
NI WSN-3212	15B3687	1	11/9/2011 10:57:33 AM	OK	Excellent	End Node	NI WSN-3212 1.2.0f0

After clicking on “add node”, a box will display asking for the type, serial number, and ID of the node you want to add. The “type” of the node can be found physically on the node, usually on the lower right hand corner of the battery cover. The serial number of the node can be found on the back of the node (also denoted S/N on the back with the labels). The ID number is an arbitrary number you can select. However, no two nodes can have the same ID number or will cause confliction with each other. The diagrams below display an example of entering the node’s credentials and successful completion of adding the node to the system.

Note: After successfully adding a node, always refresh Measurement & Automation to confirm the configuration and vitals of the node.



Wireless Channel: 12

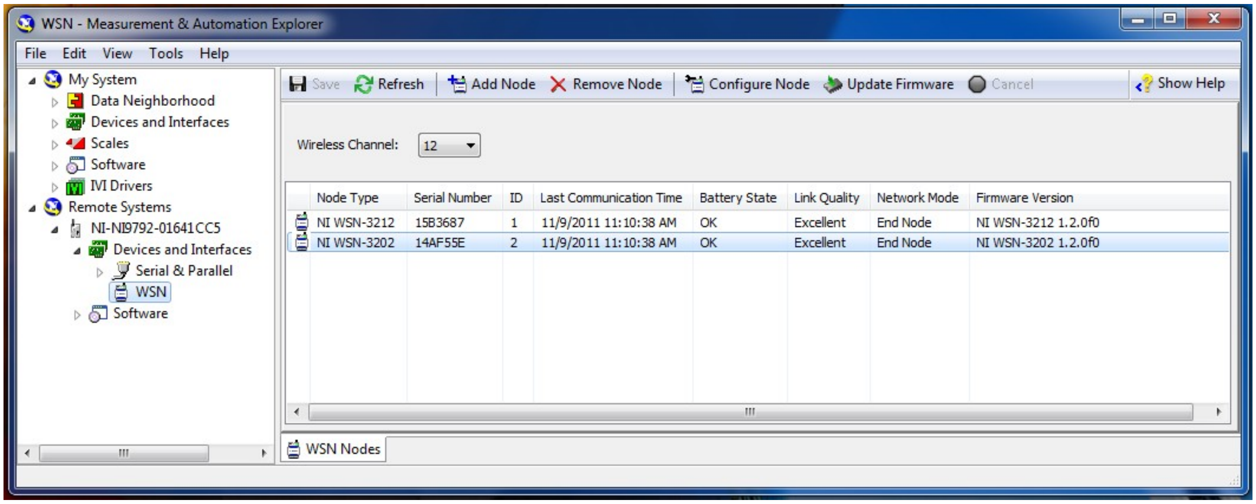
Add WSN Node

Type: NI WSN-3202

Serial Number: 14AF55E

ID: 2 (1-50)

Node Type	Serial Number	Network Mode	Firmware Version
NI WSN-3212	15B3687	End Node	NI WSN-3212 1.2.0f0



Wireless Channel: 12

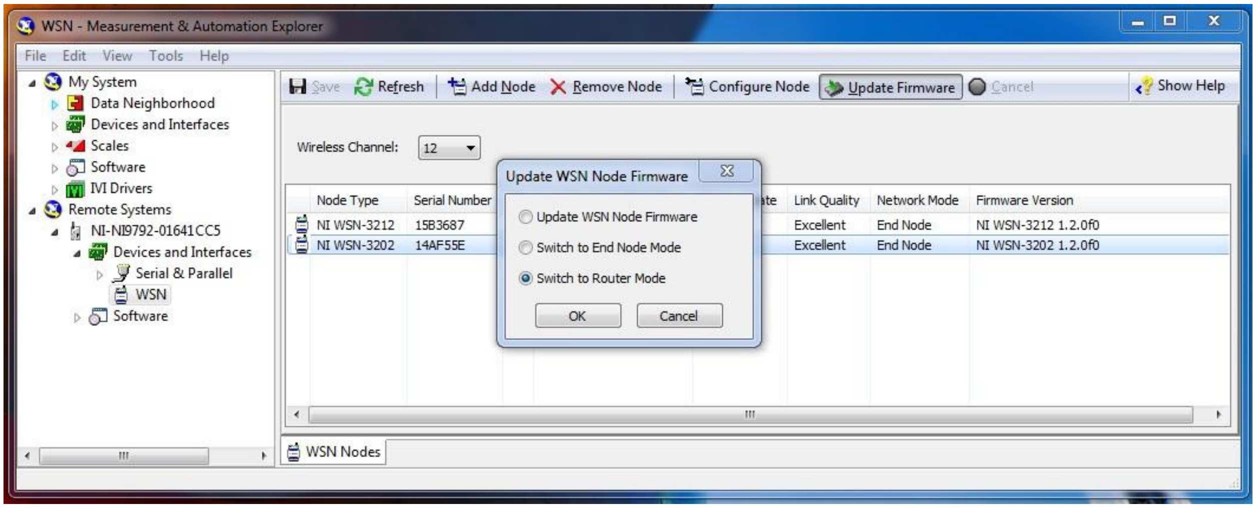
Node Type	Serial Number	ID	Last Communication Time	Battery State	Link Quality	Network Mode	Firmware Version
NI WSN-3212	15B3687	1	11/9/2011 11:10:38 AM	OK	Excellent	End Node	NI WSN-3212 1.2.0f0
NI WSN-3202	14AF55E	2	11/9/2011 11:10:38 AM	OK	Excellent	End Node	NI WSN-3202 1.2.0f0

Configuring Nodes Through Measurement & Automation

Due to limitations of the node's design and situations they are used in, the nodes can only reach a certain distance that also varies depending on the obstructions between it and the gateway. To overcome this phenomenon, the nodes can be set as a mesh router. A mesh router is a device that forwards traffic, in our case data, to and from gateways so that total range of an end node from the gateway can be increased. It is recommended to not have more than 3 mesh routers connected along a line to each other. However, nodes are typically set as an end node where they can record data and their signal strength is great enough to transmit data to the gateway.

To configure the network mode of the node(s) from an end node to mesh router, open Measurement & Automation and connect to your Gateway. Once connected, select WSN from under the tree diagram. There you will have several options available as displayed below.

Select the node you want to configure its network mode in the table. You will now select "update firmware", this is where you can update the firmware of the nodes, and choose its network mode such as being utilized as an end node or mesh router. In the figure below, it shows as an example of changing a node's network mode as an "end node" to a "mesh router"



Wireless Channel: 12

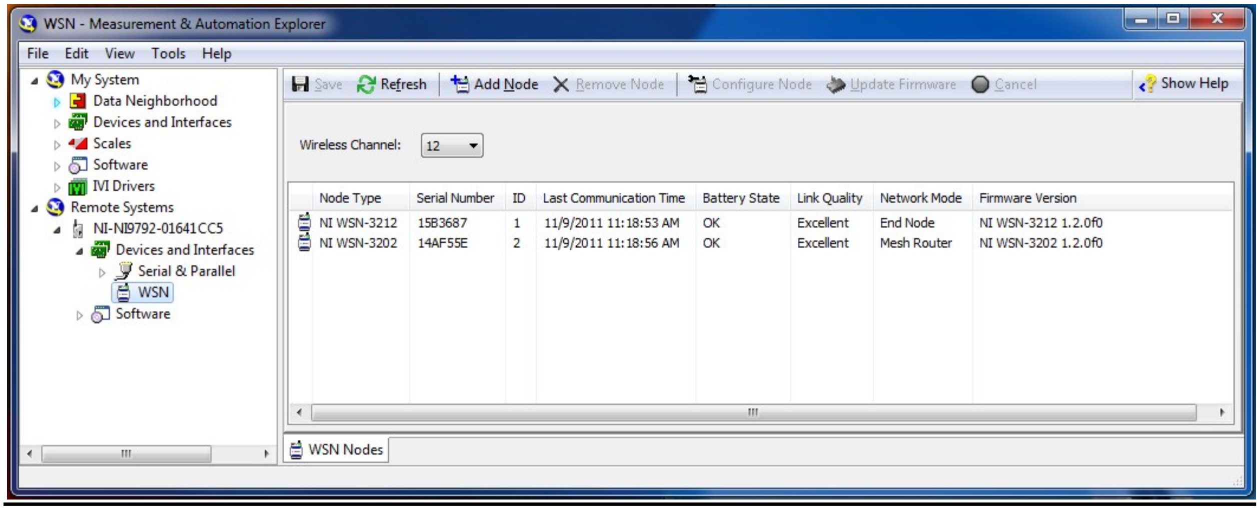
Update WSN Node Firmware

○ Update WSN Node Firmware
○ Switch to End Node Mode
● Switch to Router Mode

OK Cancel

Node Type	Serial Number	Link Quality	Network Mode	Firmware Version
NI WSN-3212	15B3687	Excellent	End Node	NI WSN-3212 1.2.0f0
NI WSN-3202	14AF55E	Excellent	End Node	NI WSN-3202 1.2.0f0

Once selecting the option, select the okay button. The node will then begin to reset and may become unresponsive for a short amount of time. It is normal for the “bars” on the node to be flashing as it is resetting its’ firmware and reconnecting to the gateway. After an amount of time, refresh Measurement & Automation at the top of the table. This will allow gateway to recognize the new configuration of the node. The figure below shows a successful change of the configuration of the specific node from an “end node” to a “mesh router”.



Wireless Channel: 12

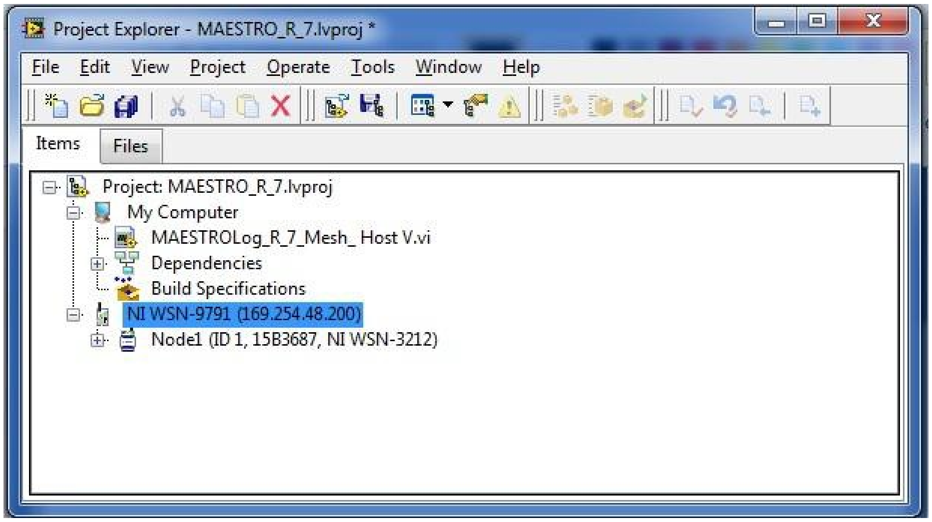
Node Type	Serial Number	ID	Last Communication Time	Battery State	Link Quality	Network Mode	Firmware Version
NI WSN-3212	15B3687	1	11/9/2011 11:18:53 AM	OK	Excellent	End Node	NI WSN-3212 1.2.0f0
NI WSN-3202	14AF55E	2	11/9/2011 11:18:56 AM	OK	Excellent	Mesh Router	NI WSN-3202 1.2.0f0

NOTE: notice how under the “Network Mode” on the table now displays “Mesh Router” of the NI-WSN 3202.

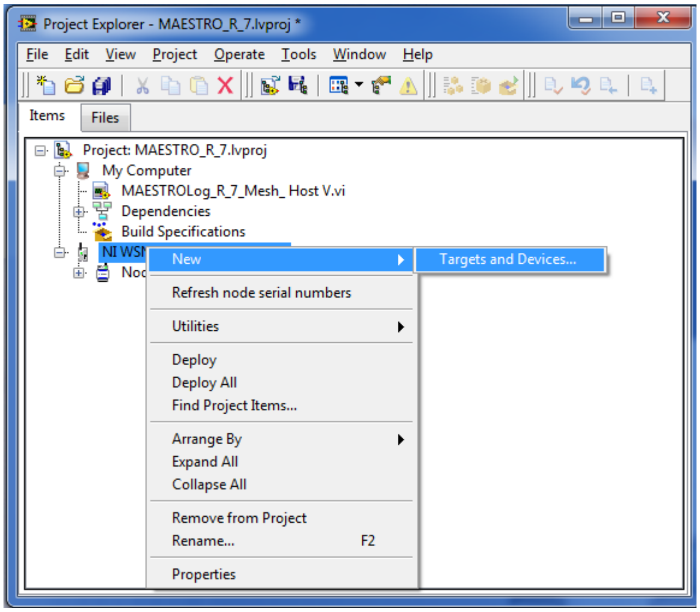
Adding Nodes to Project Folder in LabVIEW

Once adding the node to Measurement & Automation, you must then add the node to the project you want to associate it with to gather data.

First open LabVIEW and select your project, and your project explorer will display. (The figure below displays a previously added gateway and one node)

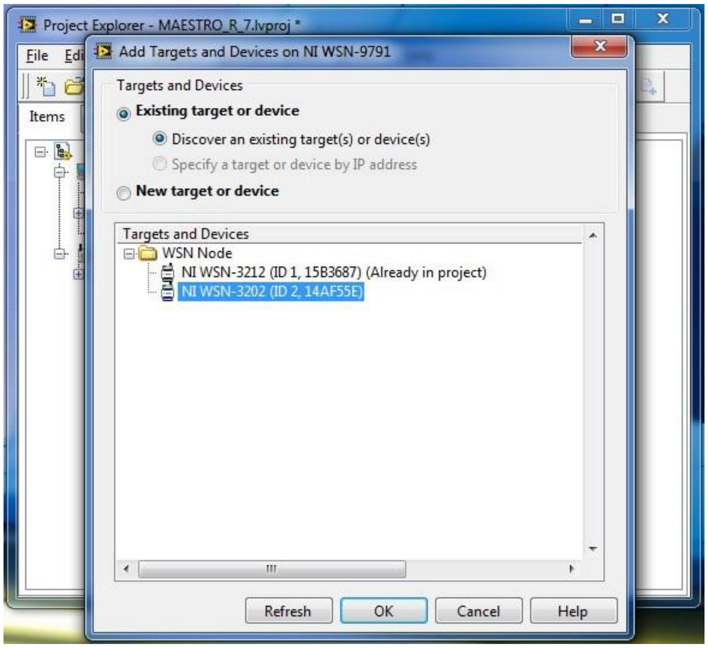


You will now right click on the gateway (NI WSN-9791 (169.254.xx.xxx)) and navigate to the "new" option, and then select/click the "Targets and Devices" option.



After selecting the "Targets and Devices" option, you will then be brought to a screen that is shown below to add the node. It is important that you have the "Existing target or device" selected. Under the table, it will display a tree diagram of a folder named "WSN Node". You may expand/contract the folder by click on the plus sign or minus sign next to the folder respectively.

Once the folder is expanded, it will display all of the nodes connected to the gateway through Measurement & Automation and previous nodes already added to the project. In this example, you would select the "NI-WSN-3202 (ID 2, 14AF55E)". You will then select okay at the bottom of the window.



Targets and Devices

● Existing target or device

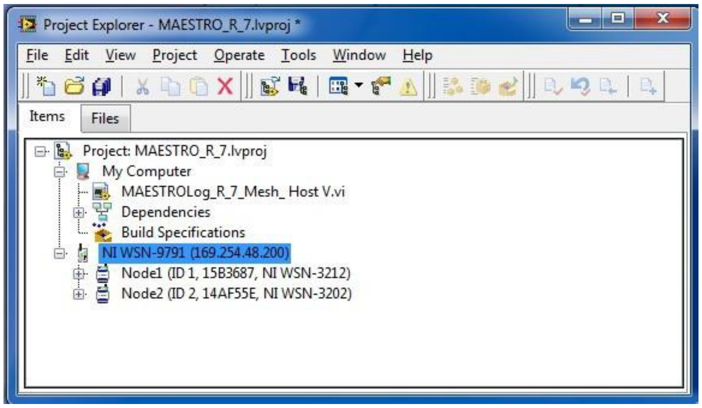
● Discover an existing target(s) or device(s)

○ Specify a target or device by IP address

○ New target or device

Targets and Devices
- WSN Node
  - NI WSN-3212 (ID 1, 15B3687) (Already in project)
  - NI WSN-3202 (ID 2, 14AF55E)

The figure below shows a successful attempt of adding a node to the project. You may now use it throughout on the block diagram to record data.

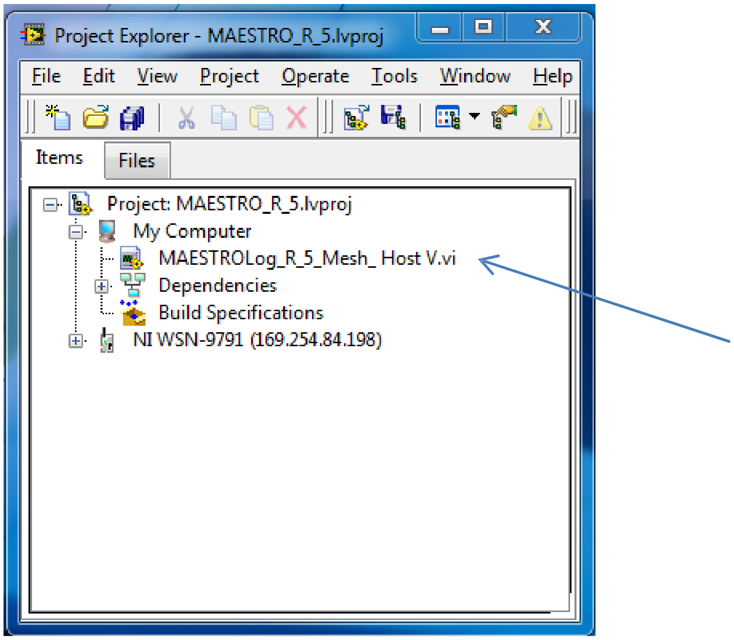


- Project: MAESTRO_R_7.lvproj
  - My Computer
    - MAESTROLog_R_7_Mesh_ Host V.vi
    - Dependencies
    - Build Specifications
  - NI WSN-9791 (169.254.48.200)
    - Node1 (ID 1, 15B3687, NI WSN-3212)
    - Node2 (ID 2, 14AF55E, NI WSN-3202)

NOTE: After adding each node, you need to right click on the gateway in the project explorer and select “Refresh node serial numbers” before making any changes in your block diagram. This will ensure they are truly connected to the gateway through Measurement & Automation along with LabVIEW.

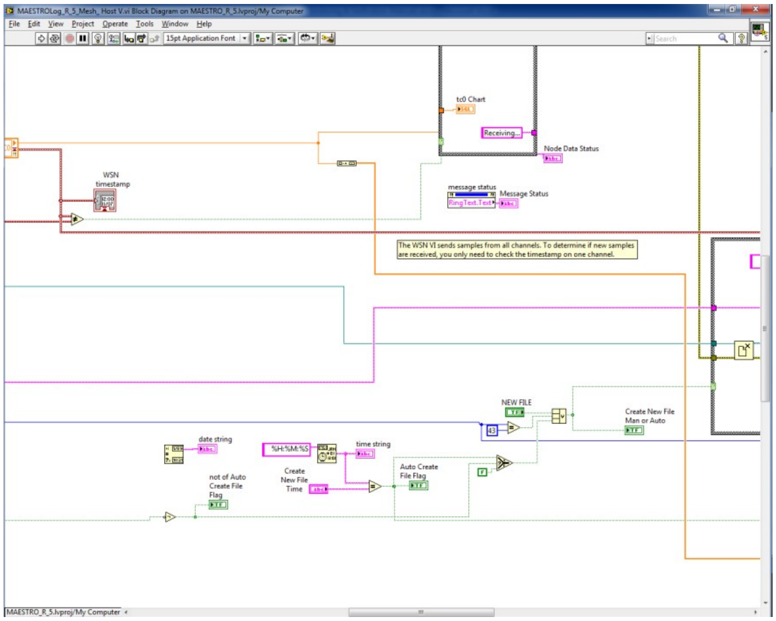
Accessing the VI and Block Diagram

A LabVIEW project consists of three main components, the vi, the Project Explorer, and the Block Diagram. Upon opening a project, the project explorer is the only widow opened.



Project: MAESTRO_R_5.lvproj
  My Computer
    MAESTROLog_R_5_Mesh_ Host V.vi
    Dependencies
    Build Specifications
  NI WSN-9791 (169.254.84.198)

The project explorer allows the user to access all the components of the program, make changes, and run the program. As previously discussed, a program is run by double clicking on the text containing ".vi". With the vi open, the block diagram is shown by holding down the keys 'ctrl' and 'e'.



The WSN VI sends samples from all channels. To determine if new samples are received, you only need to check the timestamp on one channel.

Example of a Block Diagram

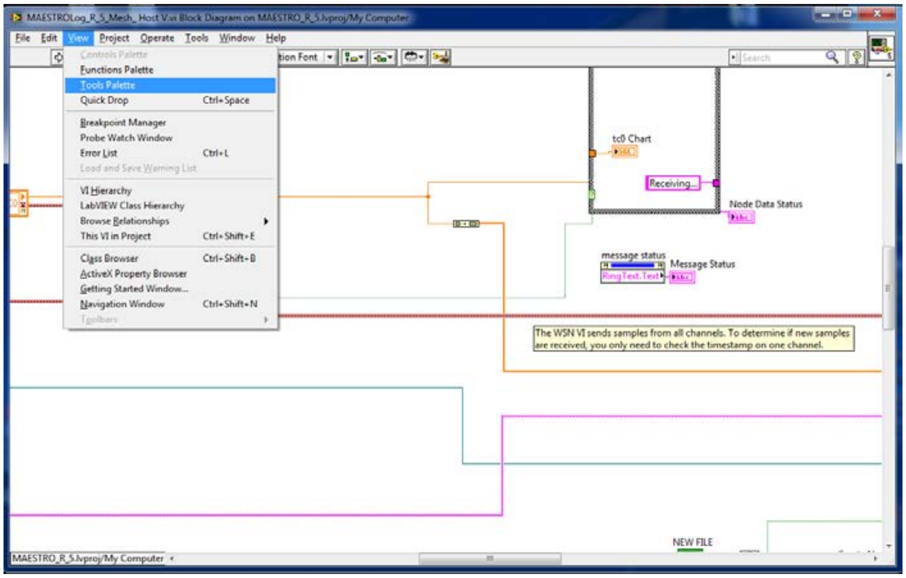
The block diagram contains all the code necessary for a program to be created. Unlike more traditional coding languages, LabVIEW employs a visual form of coding. Elements of the code are connected by wires to simulate the flow of information through the program. Like any programing language, the entirety LabVIEW cannot be learned in little time. This user's guide to

EMV will not attempt to explain all of LabVIEW to the reader, but will introduce concepts necessary to operating a program and making changes needed for application of the system. Specific applications of the program created will require different combinations of hardware specific to the needs of the location. For example, only one end node is needed to measure the current drawn to run the light in a small room, provided that the gateway may be placed within range of the wireless signal from the node. However, if a measurement of current used by many objects spread out over long distances is needed, the situation may render the use of multiple end nodes and possibly mesh routers. Changing the number of nodes and their configurations will require changes in the block diagram.

Block Diagram Editing, Basics

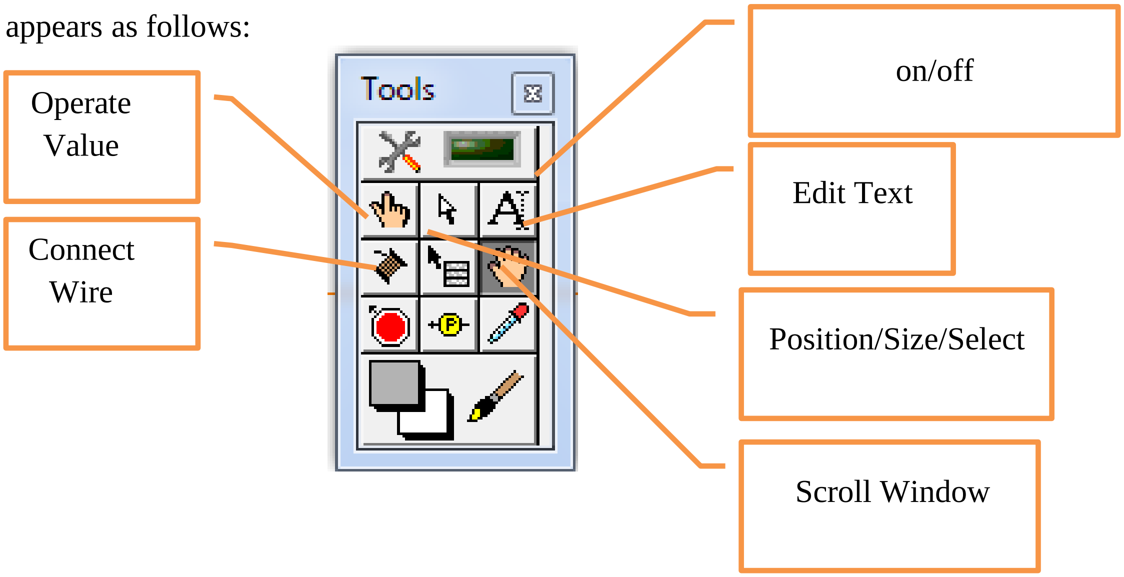
Some basics will now be introduced to assist the user in editing a block diagram. LabVIEW utilizes different pointer types for different types of changes made to a block diagram. LabVIEW defaults to automatically choosing the user's pointer type based on assumptions of the user's intent. However, sometimes auto pointer may be frustrating, as it does not always choose what the user wants. It may be preferable to turn off the automatic tool selector and manually select the type of pointer wanted.

Access to the on/off for the automatic tool selector is found in the tools palette. Click on Tools Palette in the View dropdown menu.



The WSN VI sends samples from all channels. To determine if new samples are received, you only need to check the timestamp on one channel.

The tools palette appears as follows:

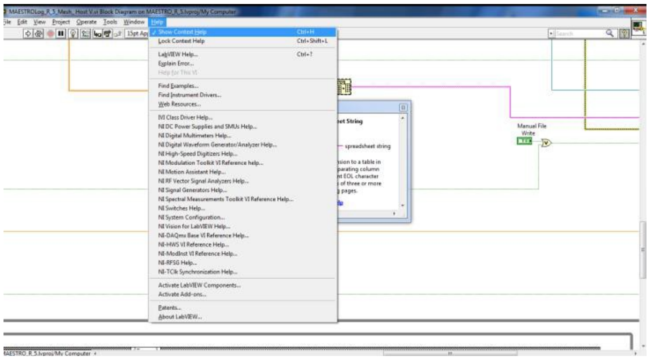


Tools may be changed automatically with automatic tool selector on, manually with tab when automatic tool selector off, or by clicking any icon on the tools palette (turns auto off). The tool names given above will be referred to elsewhere in this manual.

Operate Value: Use this tool to double click on elements in the block diagram. Double clicking brings the VI coming to the screen with the equivalent element highlighted.

Connect Wire: Used to create wires between elements of code in the block diagram. Edit Text: Used to insert text when labeling elements in the block diagram. Position/Size/Select: Used to drag, resize and select elements.

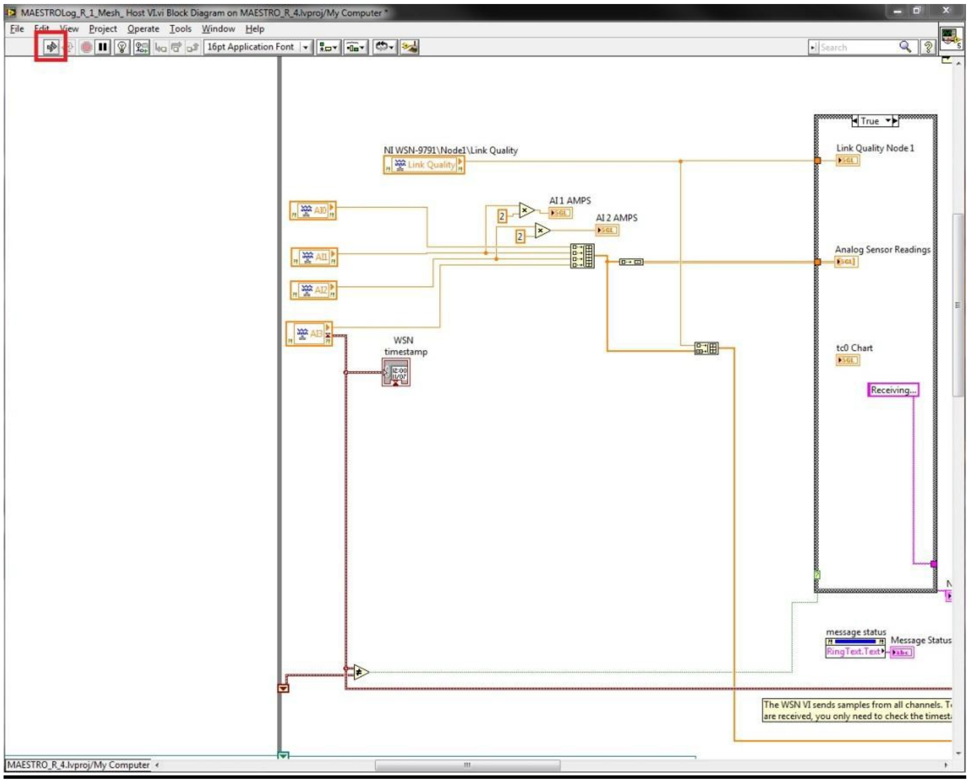
Scroll Window: Enables the user to pan through the entire diagram. This tool is very useful, as diagrams can become quite large.



Additional Note for Editing: Context Help is a useful resource for referencing the function of elements in a diagram. Turn on Context Help by selecting the first option in the help drop down menu. With Context Help open, the user may click on any element in the block diagram and a description of the function of that element will appear.

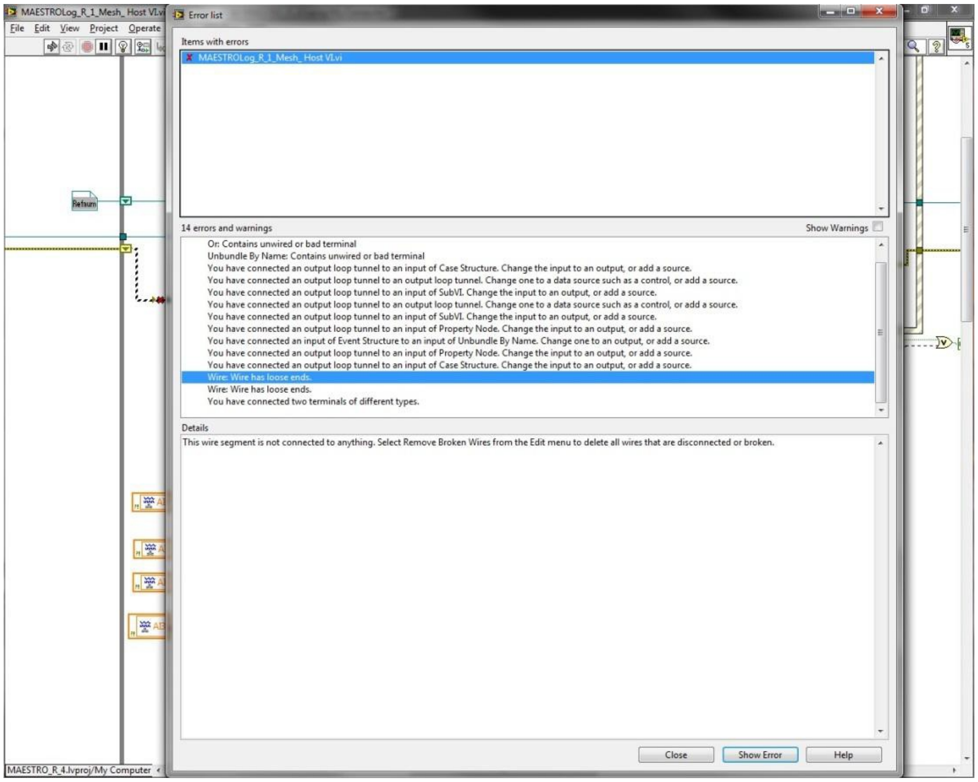
Running Programs & Identifying Errors in LabVIEW

This section is dedicated to helping provide solutions in possible errors of your programs. To run your program, open your block diagram of your program and click on the white arrow in the upper left hand corner of the window. If you have a gray or broken arrow, this is an indication of an error within your program. Another indication of an error is when you actually run the program. The figure below displays a program with a broken, gray arrow; indicating of an unknown error in the program.



The WSN VI sends samples from all channels. T
are received, you only need to check the timest

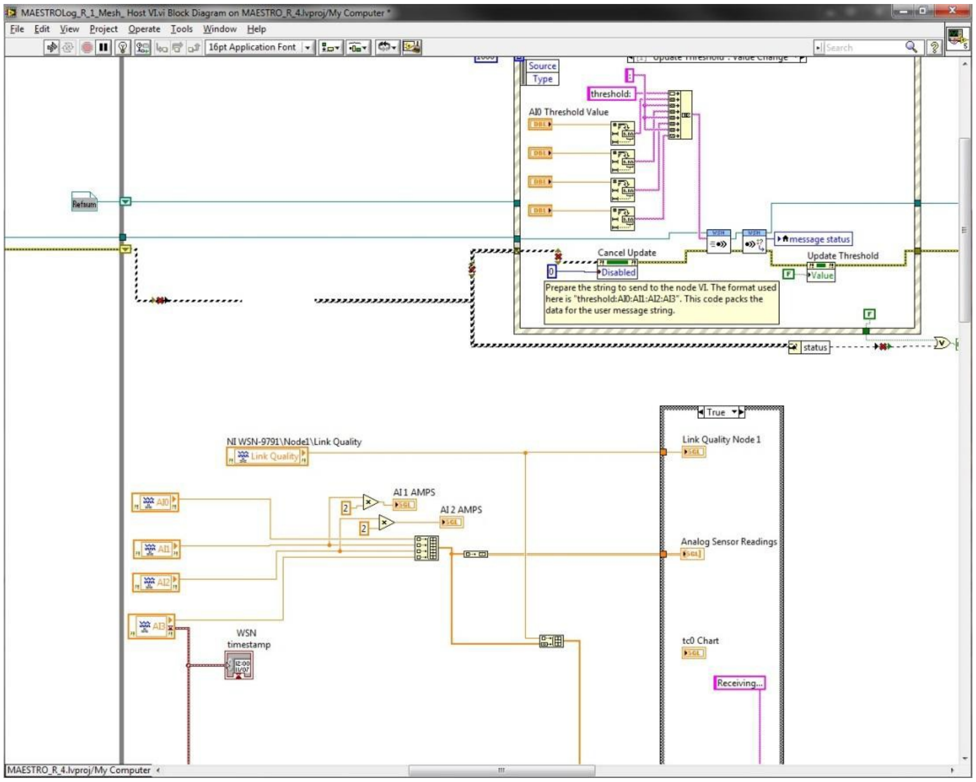
To determine where the error is in the program, click on the broken, gray arrow just as if you would be running the program. Doing this will open a new window and display all the errors in the program.



```
Or: Contains unwired or bad terminal
Unbundle By Name: Contains unwired or bad terminal
You have connected an output loop tunnel to an input of Case Structure. Change the input to an output, or add a source.
You have connected an output loop tunnel to an output loop tunnel. Change one to a data source such as a control, or add a source.
You have connected an output loop tunnel to an input of SubVI. Change the input to an output, or add a source.
You have connected an output loop tunnel to an output loop tunnel. Change one to a data source such as a control, or add a source.
You have connected an output loop tunnel to an input of SubVI. Change the input to an output, or add a source.
You have connected an output loop tunnel to an input of Property Node. Change the input to an output, or add a source.
You have connected an input of Event Structure to an input of Unbundle By Name. Change one to an output, or add a source.
You have connected an output loop tunnel to an input of Property Node. Change the input to an output, or add a source.
You have connected an output loop tunnel to an input of Case Structure. Change the input to an output, or add a source.
Wire: Wire has loose ends.
Wire: Wire has loose ends.
You have connected two terminals of different types.
```

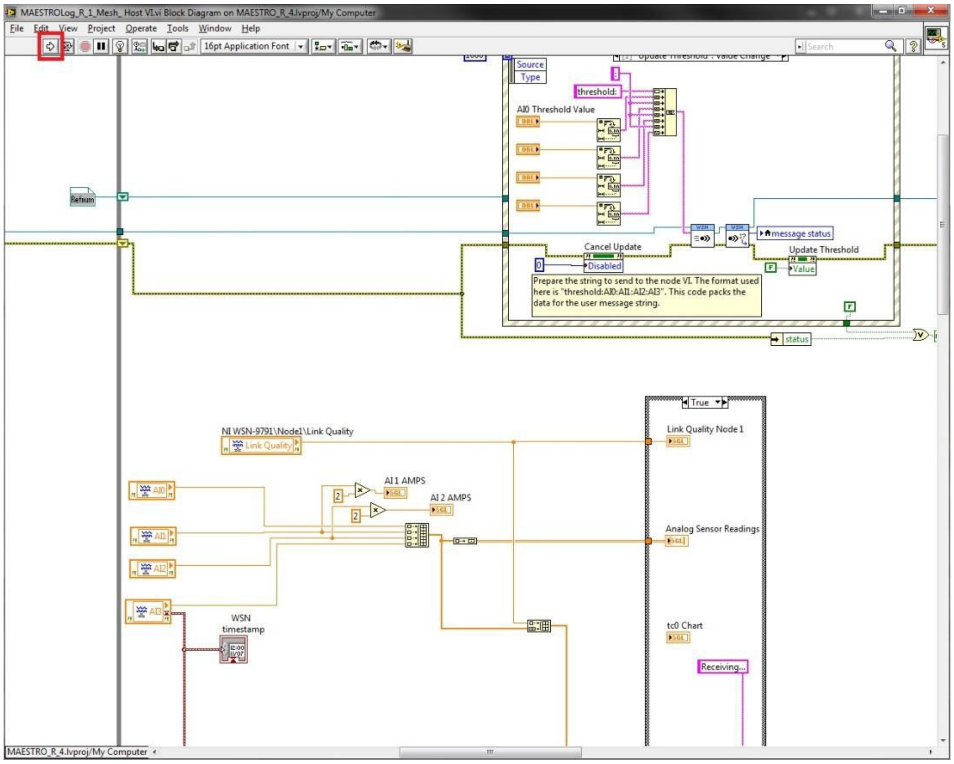
```
This wire segment is not connected to anything. Select Remove Broken Wires from the Edit menu to delete all wires that are disconnected or broken.
```

As you can see, there are several errors within the program and we are not exactly sure where these errors are being generated by the block diagram. To locate the errors, double-click on the error you are interested in and the LabVIEW will direct you to the elements of the block diagram that are generating the error. In this case, we selected the error, “wire has loose end” and directed us to the loose wires as shown in the figure below.



Prepare the string to send to the node VI. The format used here is "threshold:AI0:AI1:AI2:AI3". This code packs the data for the user message string.

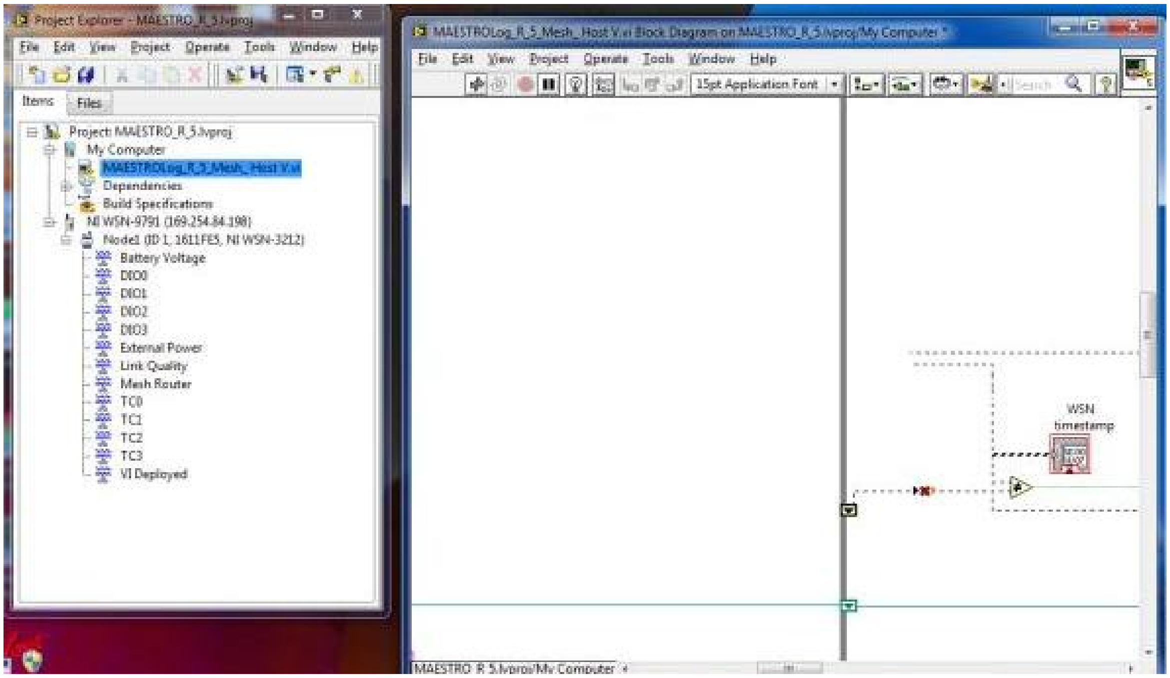
Once we reconnect the loose wires, all the errors are fixed and we receive a white arrow in the upper left hand corner. This indicates there are no errors in the program and can now we run. The figure below displays the white arrow and successful, error-free program.



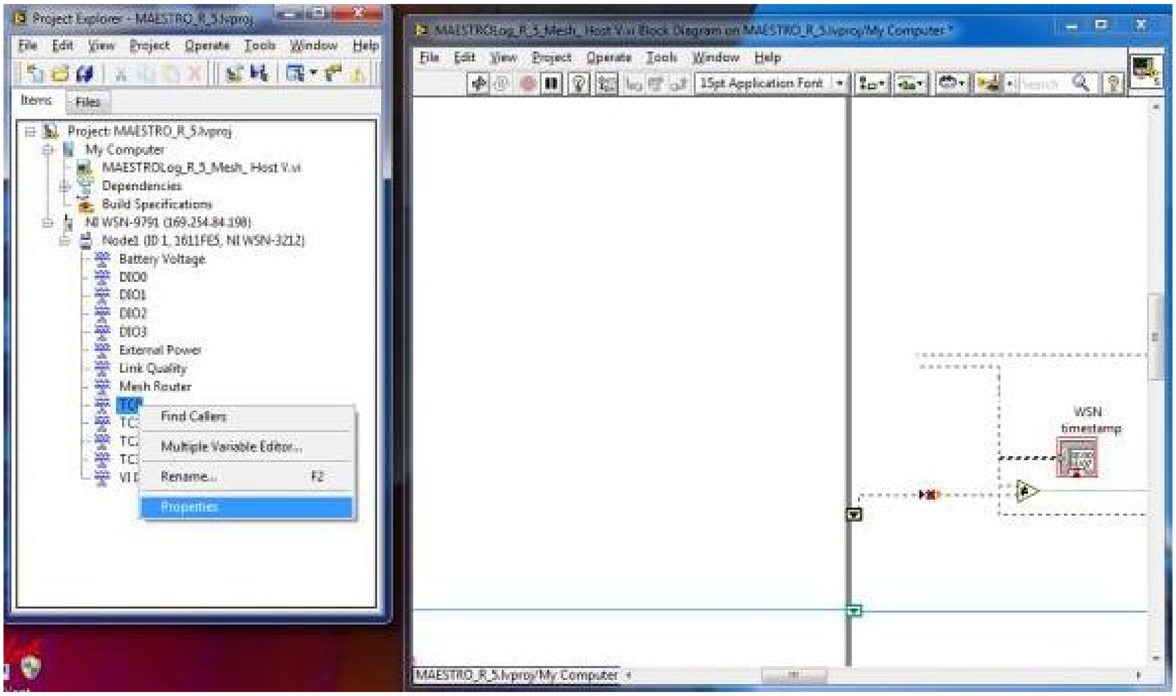
Prepare the string to send to the node VI. The format used here is "threshold:AI0:AI1:AI2:AI3". This code packs the data for the user message string.

Adding/Editing a Node to the Block Diagram (NI-9791)

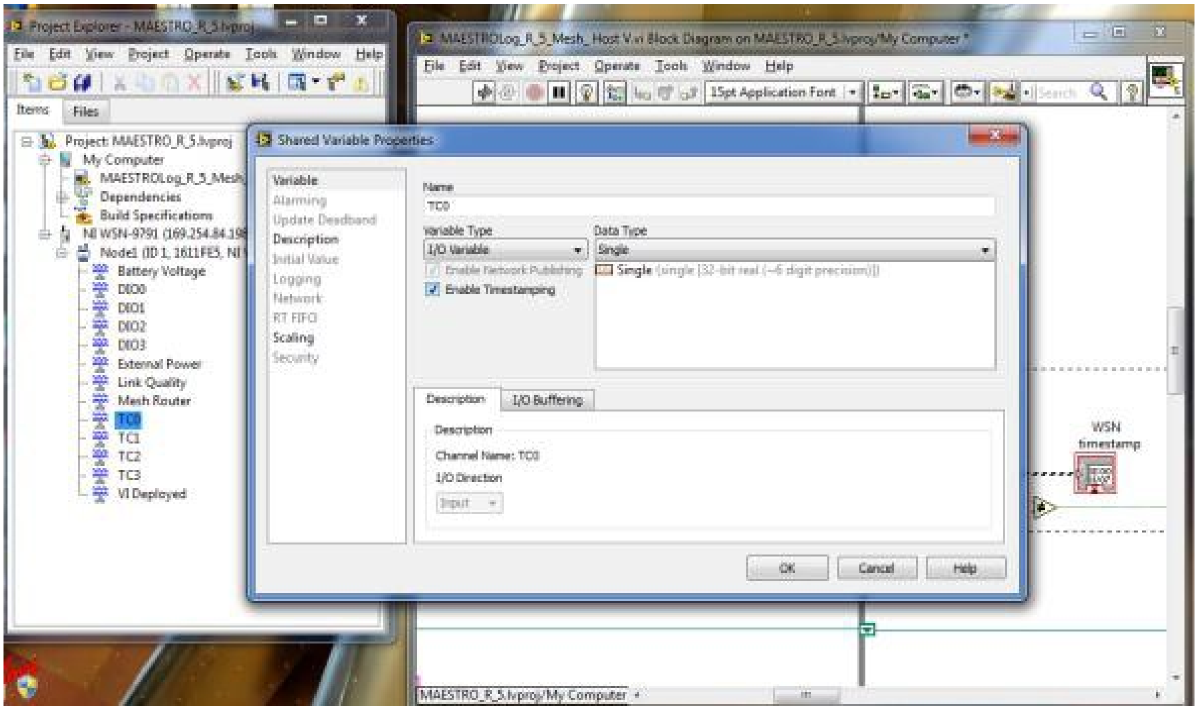
After a node has been added to the system, an icon will appear under the icon for the gateway in the project explorer.
Choose the + to expand the drop down menu for the node. This menu displays all the inputs for the selected node.



A working program must have one node sending a time stamp. To enable time stamping, right click on the input variable that you wish to add to the block diagram. Select properties.



If the variable is needed as a time stamp, check the box labeled enable timestamping. If the variable is not needed as a time stamp, there is no need to check the box.



Name: TC0

Variable Type: I/O Variable

Data Type: Single

☐ Enable Network Publishing

☑ Enable Timestamping

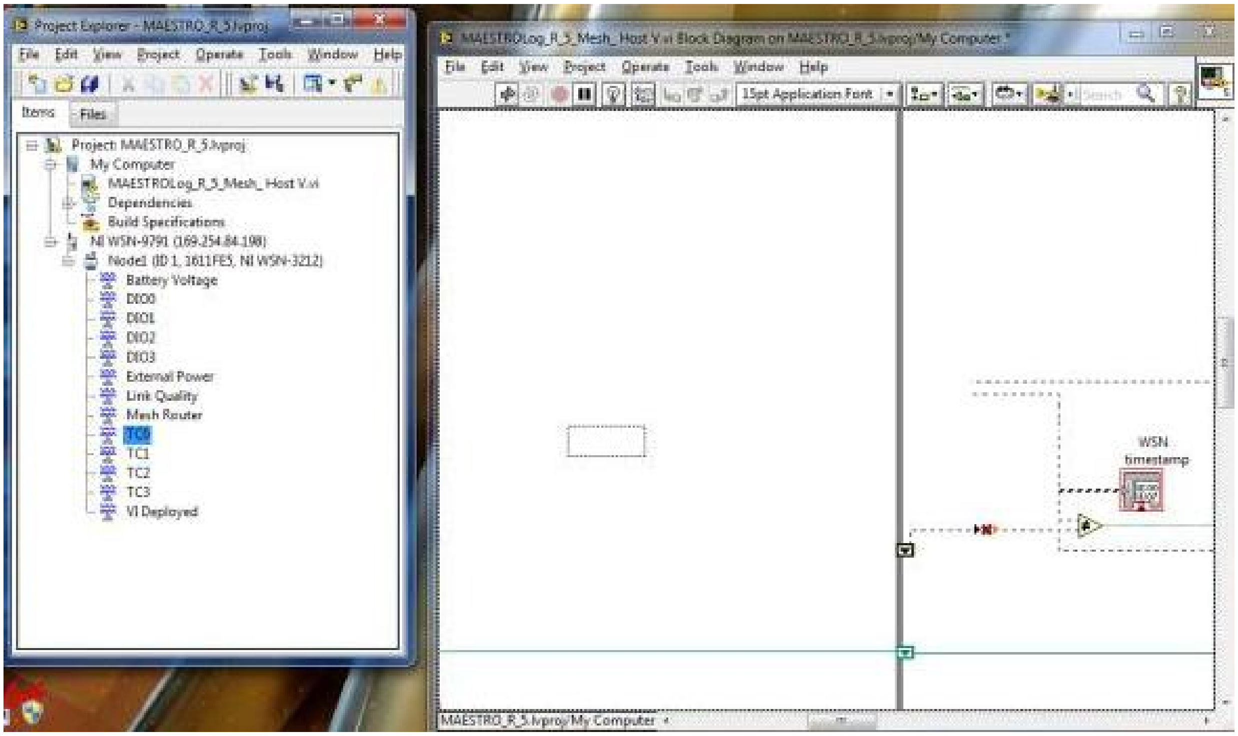
Single (single [32-bit real (~6 digit precision)])

Description

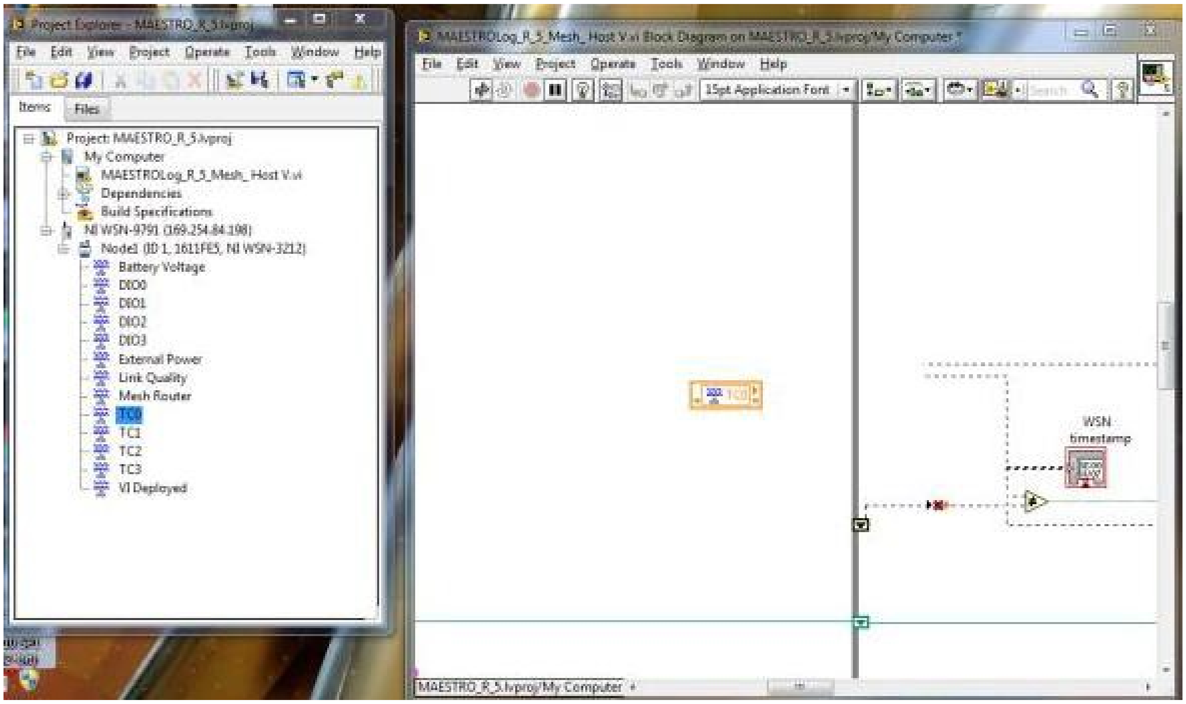
Channel Name: TC0

I/O Direction: Input

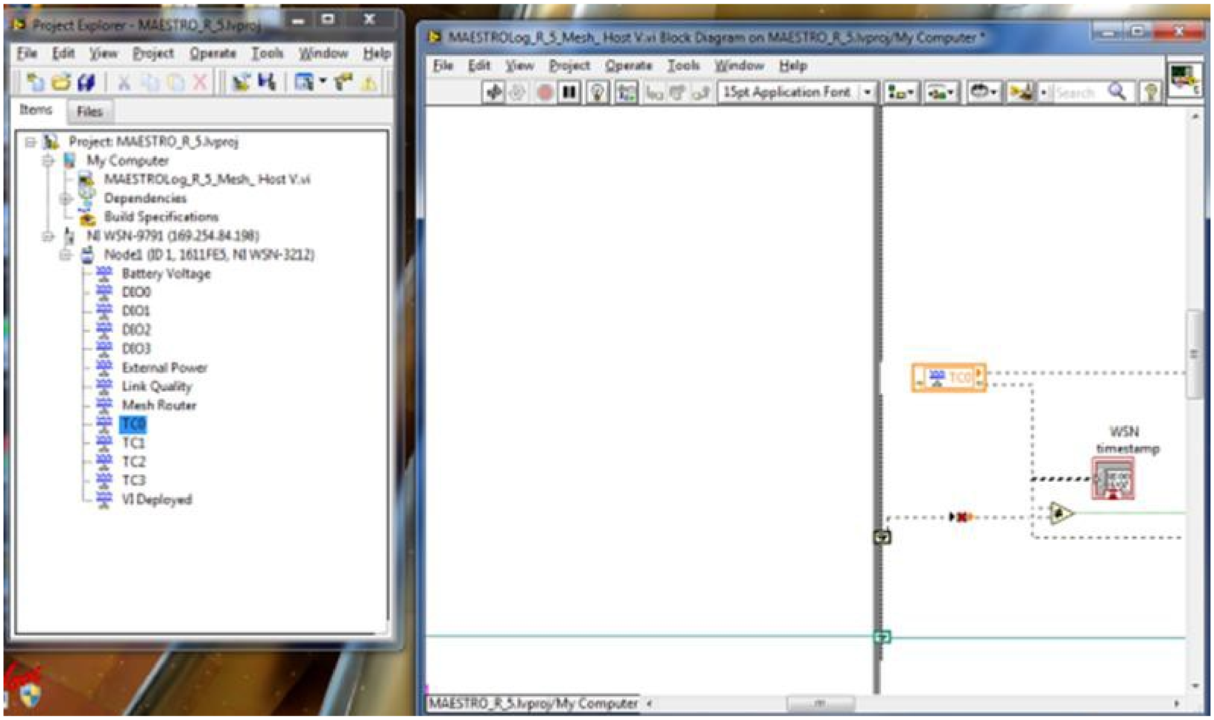
Click on the desired variable and drag it from the project explorer and into the block diagram.



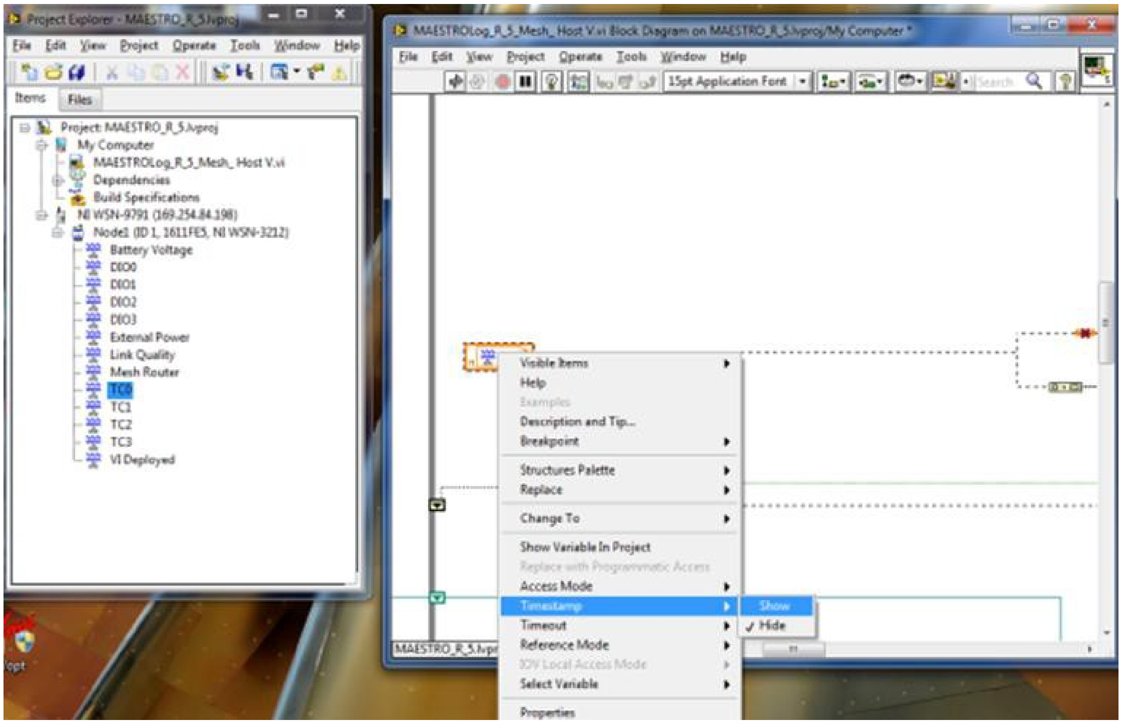
After releasing the mouse button, the variable will turn orange and remain in its specified location.



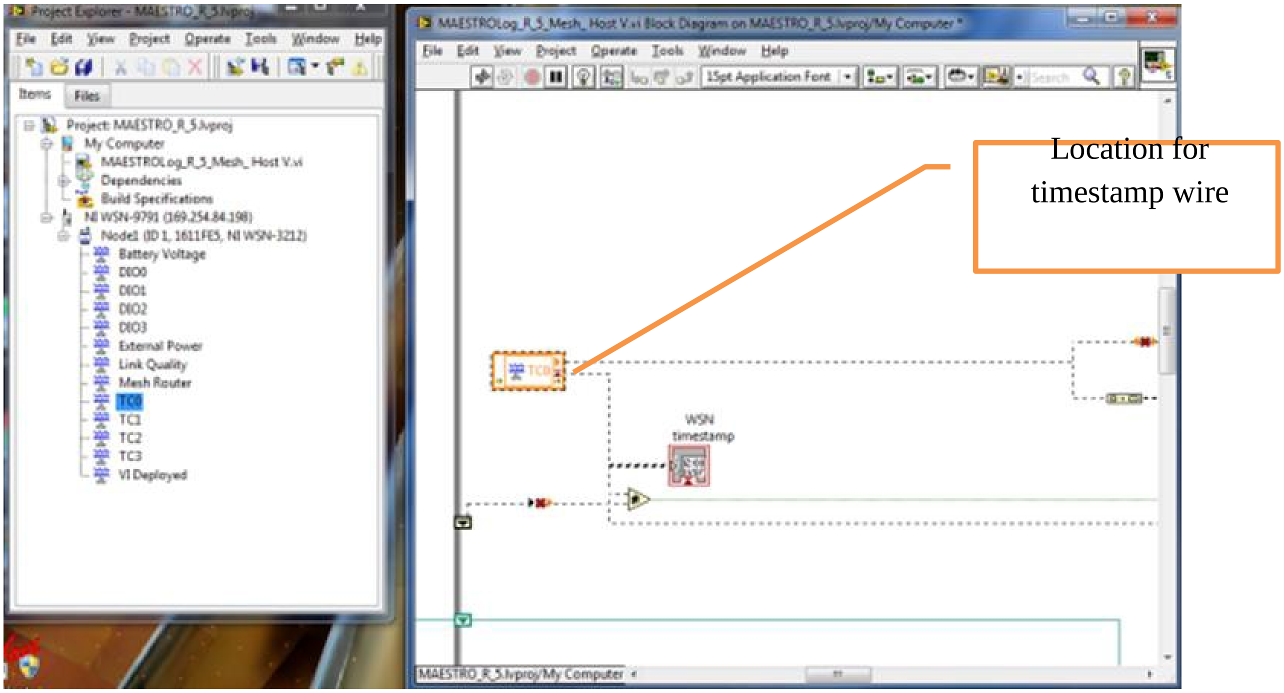
Use the Position/Size/Select tool to move the variable, or any other block diagram objects to desired positions if needed.



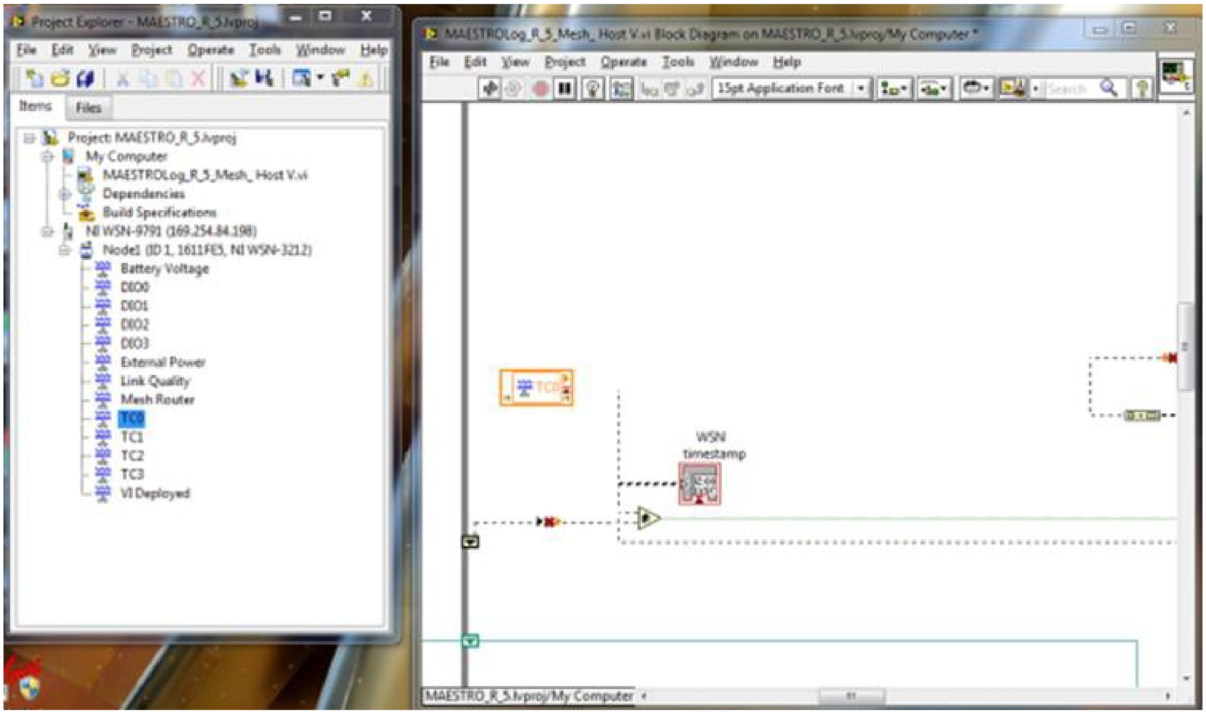
In this particular program, the variable is needed as a timestamp. Right click on the variable and select “show” under the timestamping option.



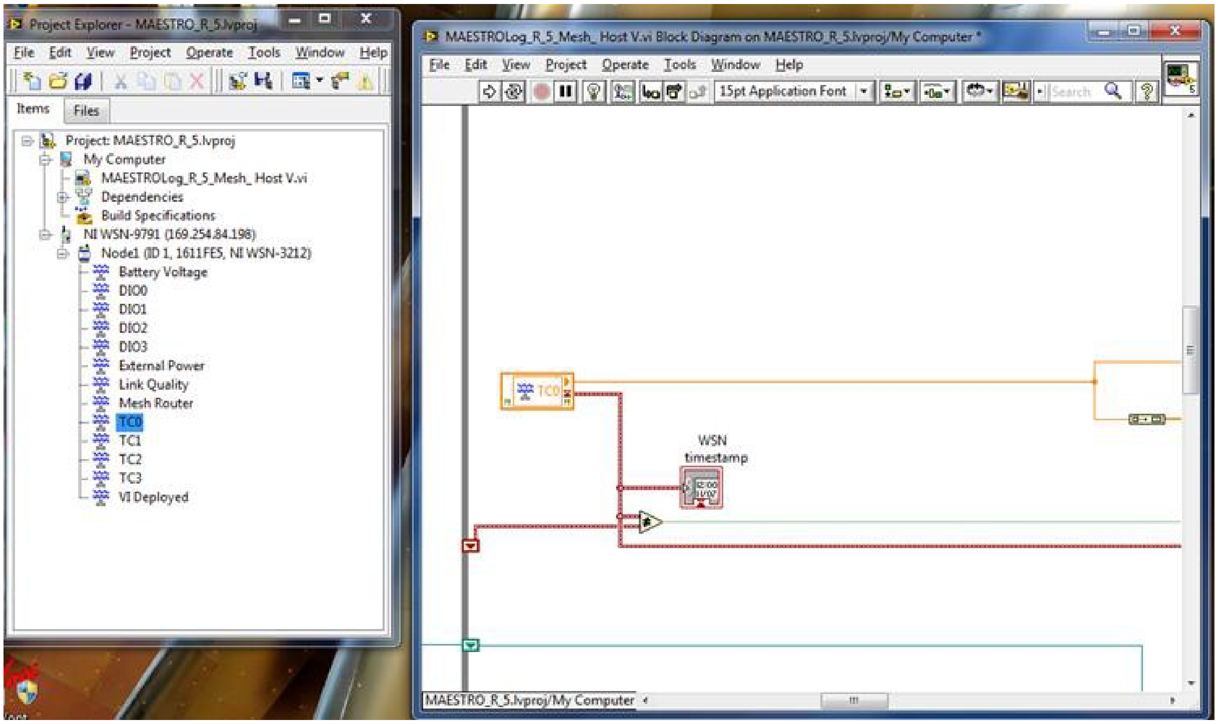
If “show” timestamping is activated the variable icon will change slightly. A timestamp output will appear above “error out” on the orange icon for the variable.


Location for timestamp wire

Old wires may need to be deleted when editing an existing block diagram. Select a wire with the Position/Size/Select pointer and press delete to delete it.

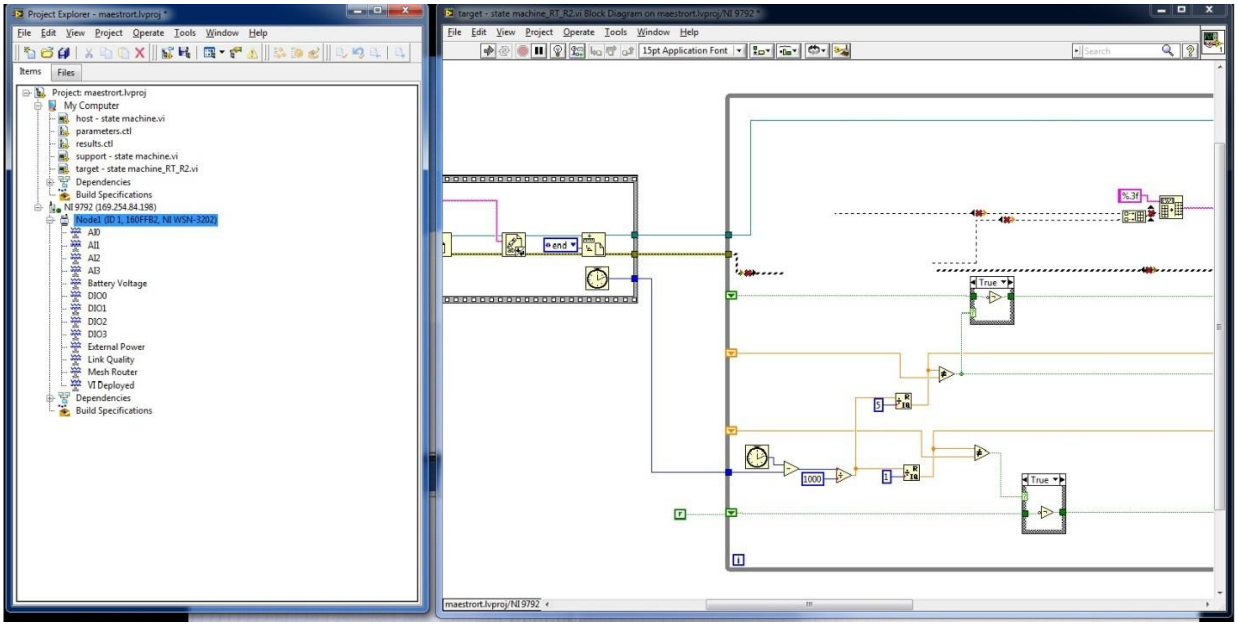


Use the connect wire tool to connect the variable with the necessary wires in the diagram. Notice that in this example, connecting the wires made the broken arrow in the top right of the screen turn solid white. Broken arrows signify an incomplete program that will not run.

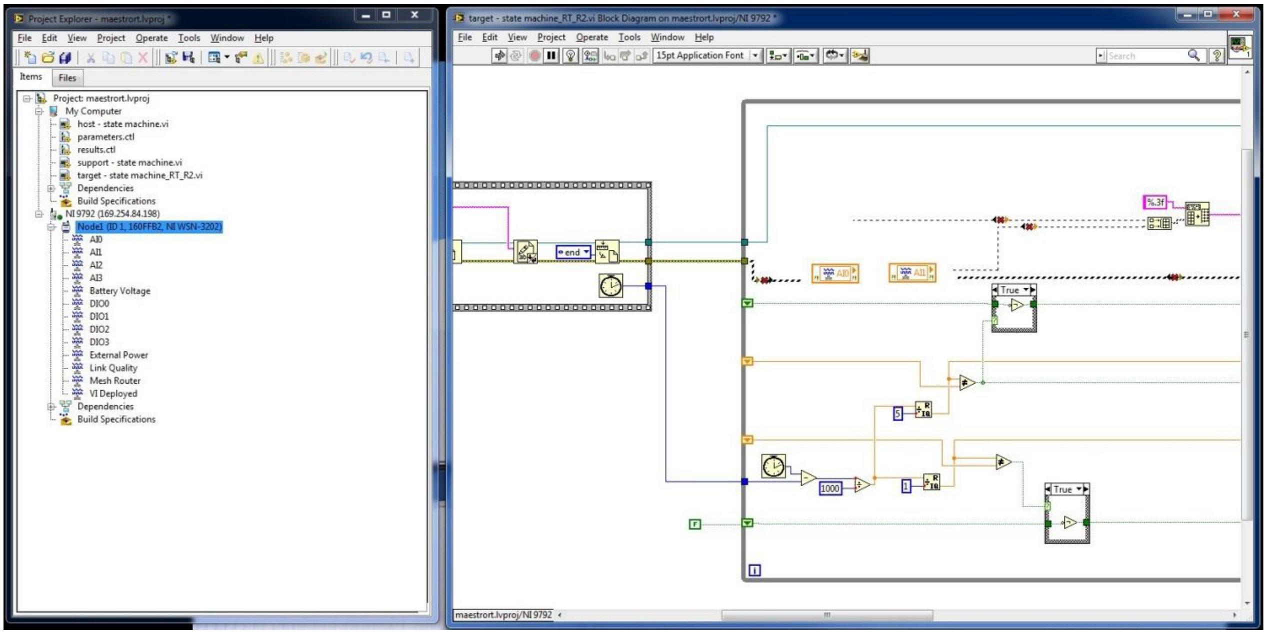


Adding/Editing a Node to the Block Diagram (NI-9792)

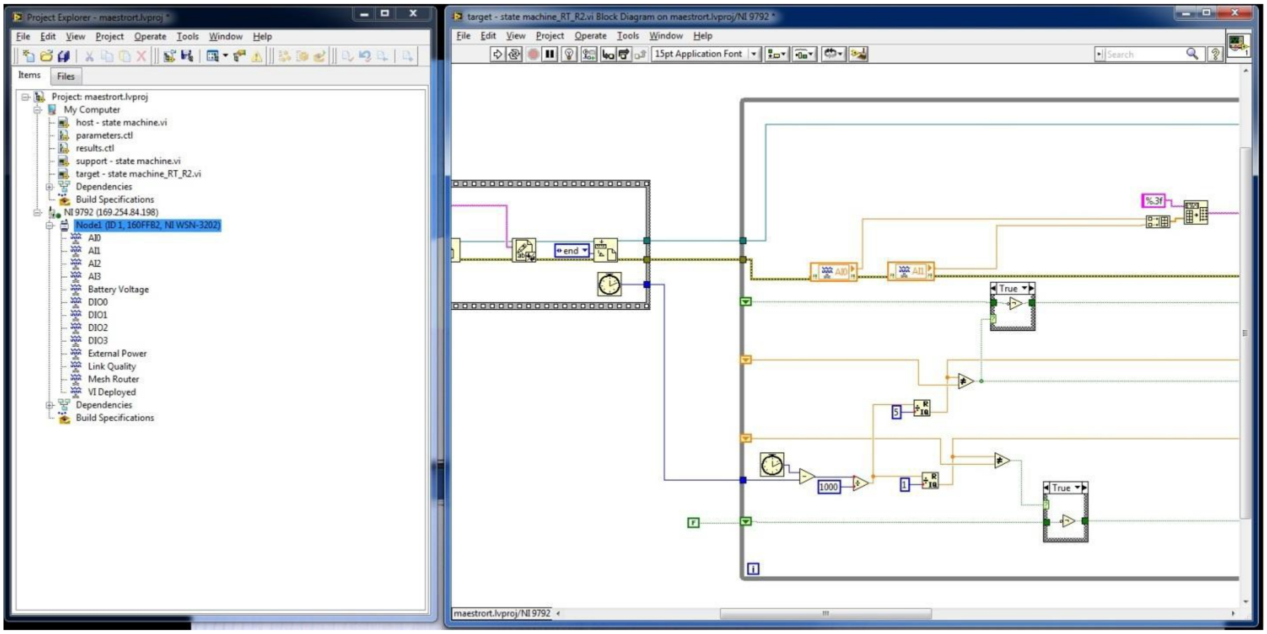
The process for adding a node to the block diagram is very similar to that of the NI-9791 with the exception of not using a timestamp function. After a node has been added to the system, an icon will appear under the icon for the gateway in the project explorer. Choose the + to expand the drop down menu for the node. This menu displays all the inputs for the selected node.



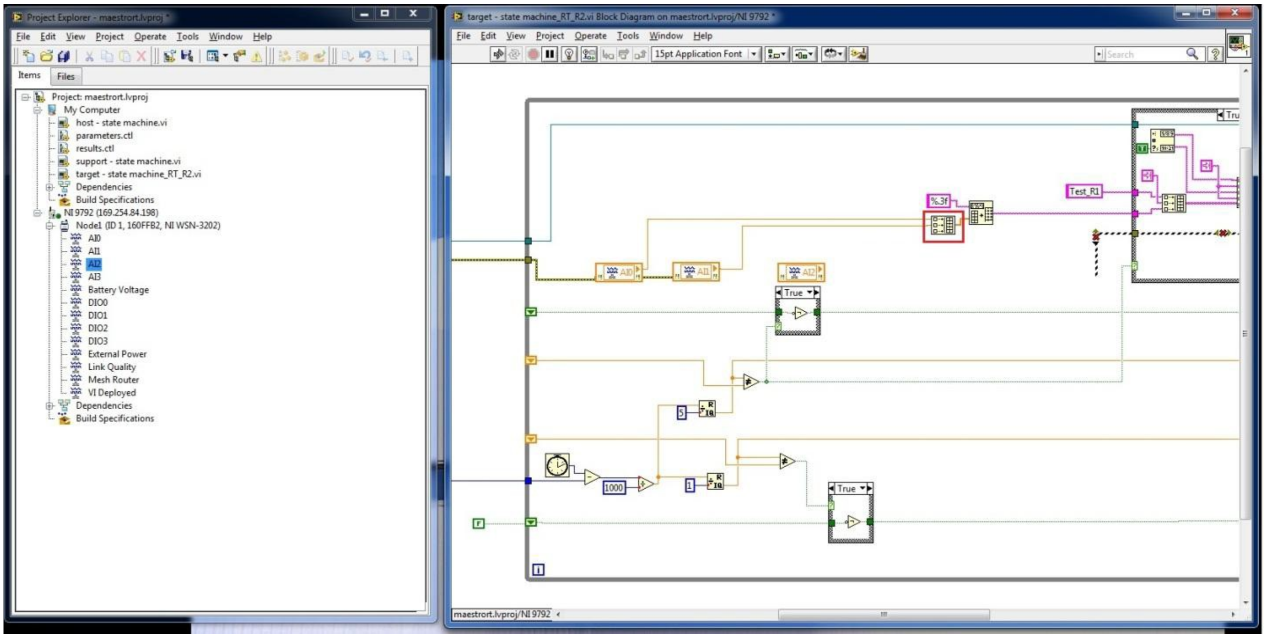
Click on the desired variable and drag it from the project explorer and into the block diagram. After releasing the mouse button, the variable will turn orange and remain in its specified location. In this case, we will be selecting Node1's AI0 and AI1 inputs to the block diagram.

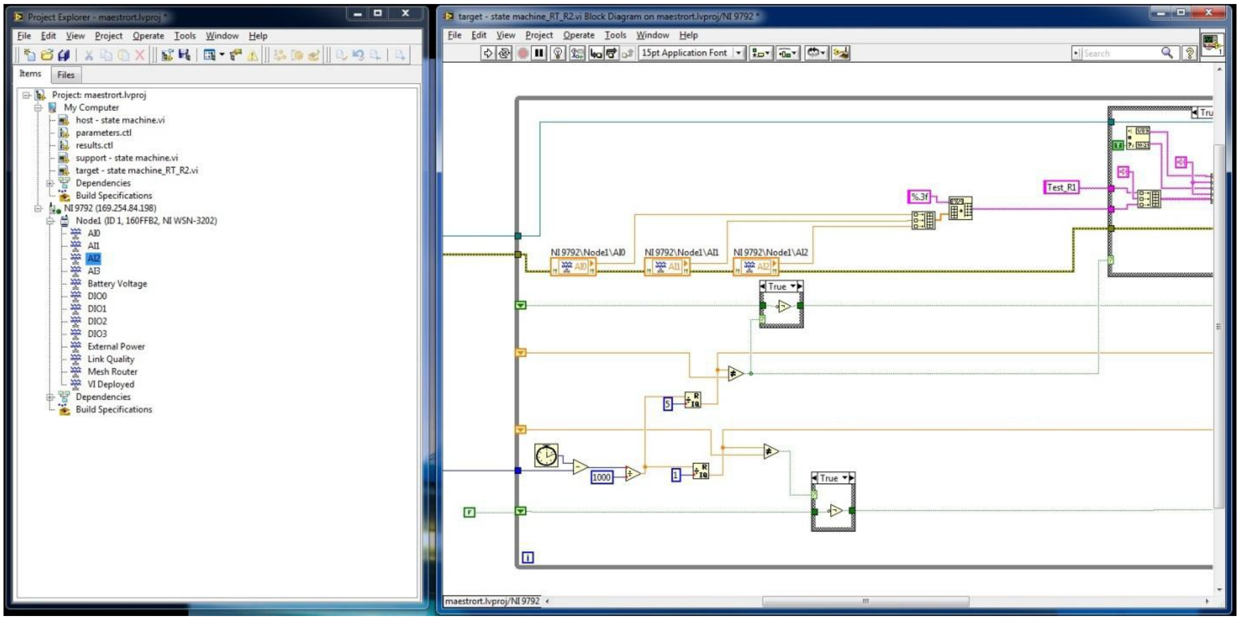


Old wires will need to be deleted when editing an existing block diagram. Select a wire with the Position/Size/Select pointer and press "delete" to delete it. Then continue to wire the input with the appropriate connections.



However for this setup, the program can only handle two inputs or measurements at a time. Therefore we will need to modify the program accordingly to how many inputs we want. In this example, we will be adding three inputs (Node1’s AI0, AI1, and AI2). Following the beginning steps by selecting the desired inputs and dragging them to the block diagram, as you can see we already have AI0 and AI1 wired in. To add AI2, we will need to modify the program’s array builder which is highlighted in the figure below. To modify this, select the Position/Size/Select tool and hover over the bottom of the build array structure. The tool will then physically change to a double arrow, or “↨”. Since we desire more inputs for the build array, click and pull down on the structures for the desired number of inputs. In our case, we will need three inputs of the build array structure. Then continue to wire the input with the appropriate connections as previously done before.



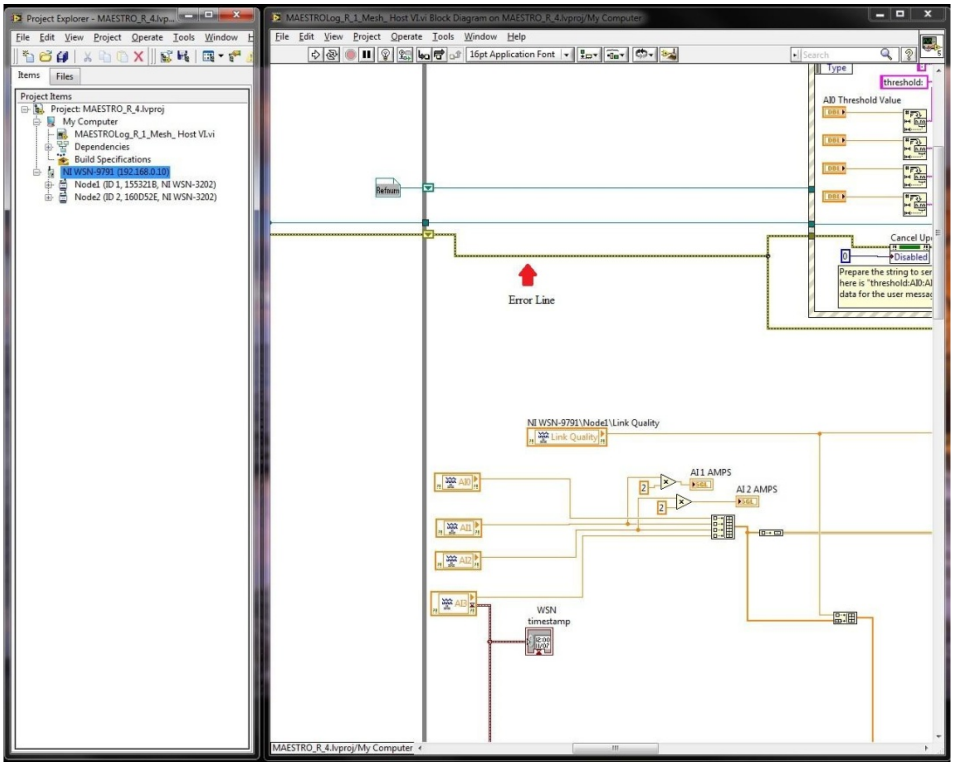


After changing the number of inputs, we will have to alter the data file's titles/headings for each measured input.

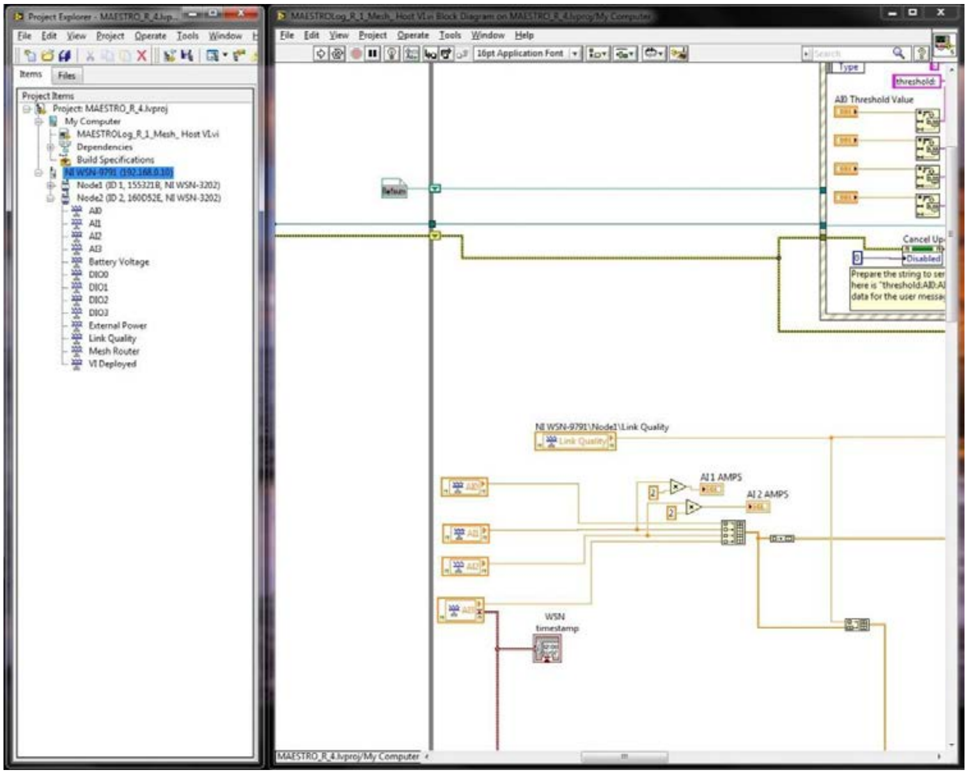
Adding A Mesh Router Through LabVIEW (NI-9791)

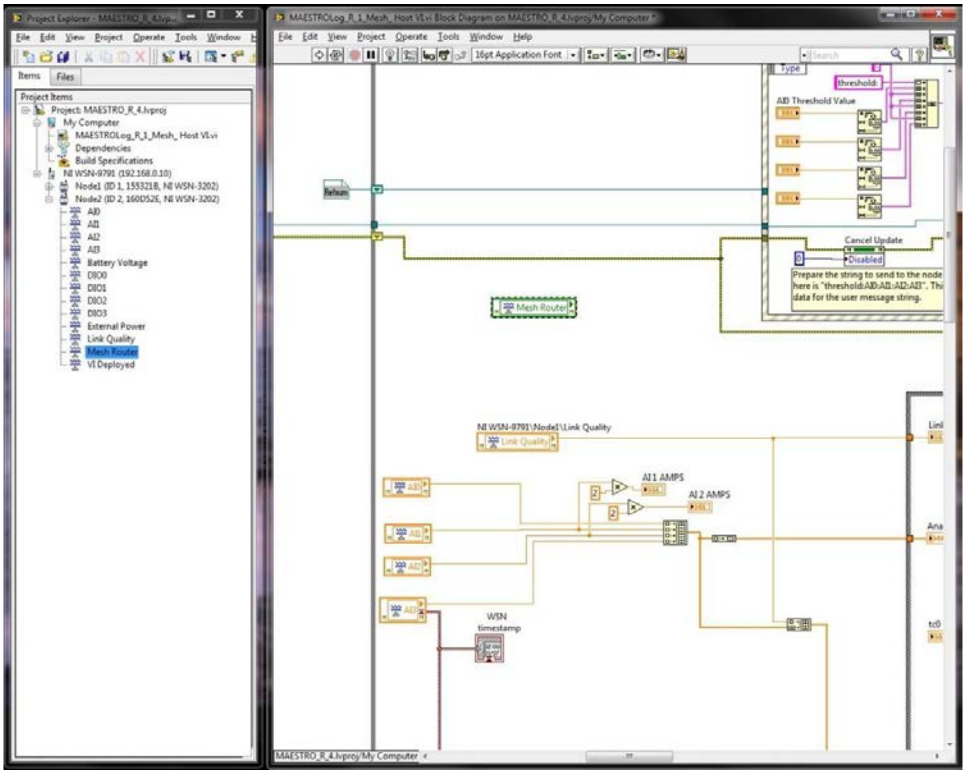
The next step (optional - depending on the geography of your area) is adding the mesh router to the project to be recognized by the gateway. It is important to realize as well that while the node is configured as a mesh router, it cannot measure any type of data. Additionally, a constant power supply is recommended as the mesh router is constantly powered and uses more power than a typical end node.

First, open the corresponding project you would like to add a mesh router to, along with the block diagram for measurements. From the project explorer under the gateway portion, expand the tree diagram of the node you would like to use as a mesh router. Locate the "mesh router" input of the node. For this example, we will be adding node #2 as a mesh router to the program.

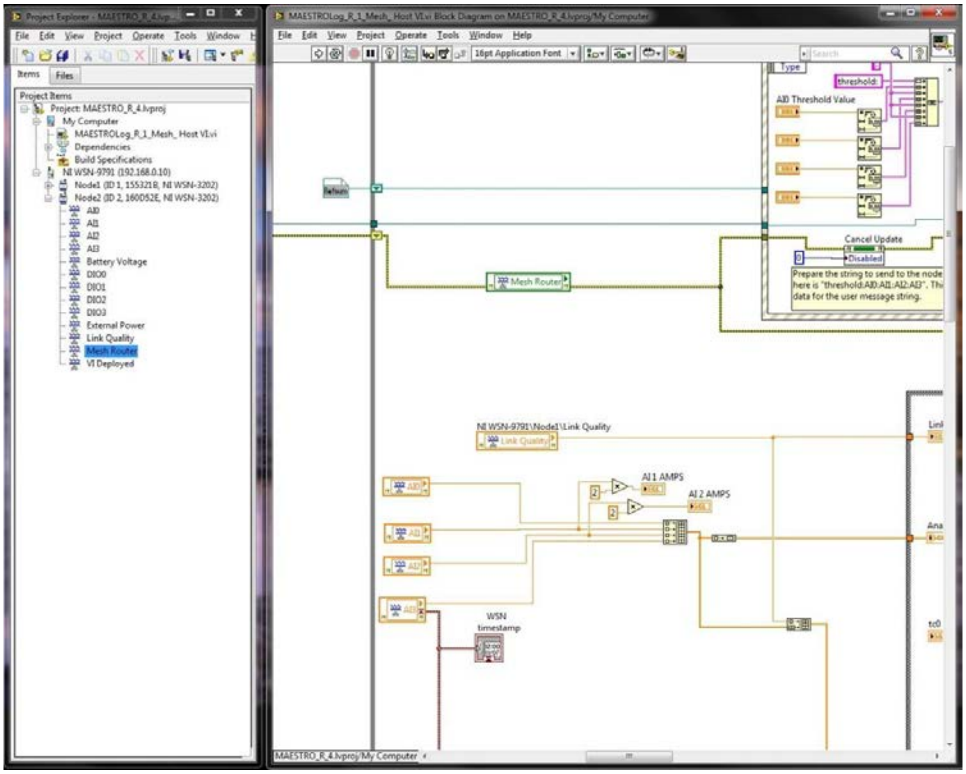


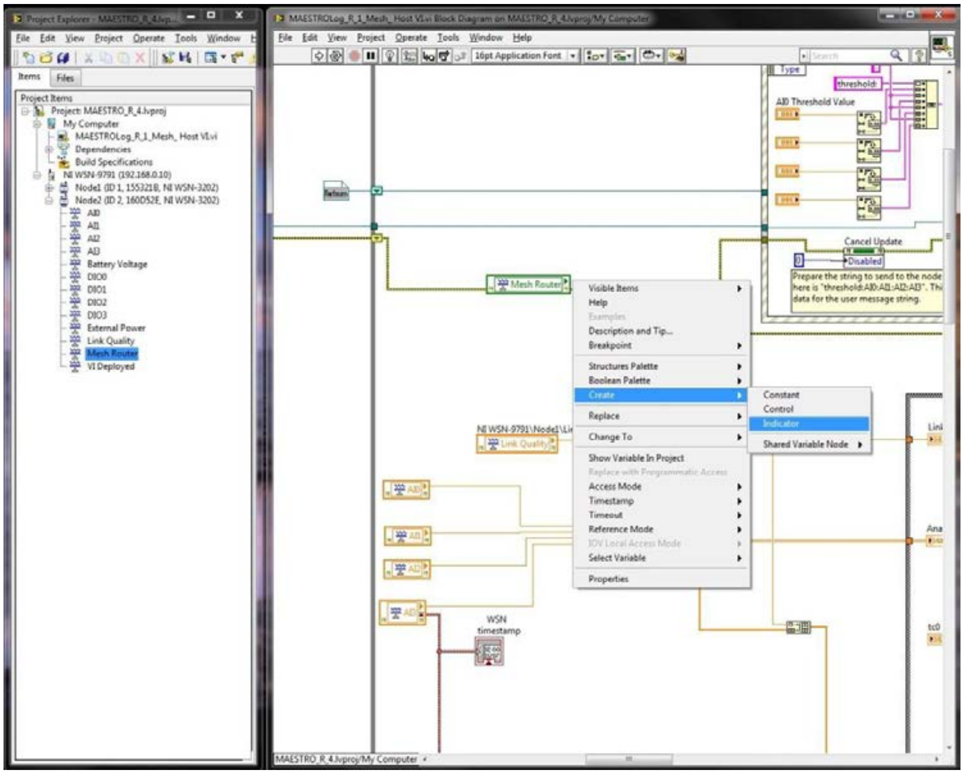
Expand the tree diagram of the node you would like to use as a mesh router. Then proceed to click and drag the "Mesh Router" input to the block diagram, just as you would do for adding an input for a end node (i.e. AI0, AI1, AI2, etc.). Also, delete any existing wires/connections that the "mesh router" input will need, specifically the "error line".


Project Explorer - MAESTRO_R_4.lvp...
File Edit View Project Operate Tools Window
Items Files
Project Items
Project: MAESTRO_R_4.lvproj
My Computer
MAESTROLog_R_1_Mesh_ Host VI.vi
Dependencies
Build Specifications
NI WSN-9791 (192.168.0.10)
Node1 (ID 1, 155321B, NI WSN-3202)
Node2 (ID 2, 160D52E, NI WSN-3202)
AI0
AI1
AI2
AI3
Battery Voltage
DIO0
DIO1
DIO2
DIO3
External Power
Link Quality
Mesh Router
VI Deployed
MAESTROLog_R_1_Mesh_ Host VI.vi Block Diagram on MAESTRO_R_4.lvproj/My Computer
File Edit View Project Operate Tools Window Help
16pt Application Font
Search
Type
threshold:
AI0 Threshold Value
Return
Cancel Up
Disabled
Prepare the string to ser here is "threshold:AI0:AI data for the user messa
NI WSN-9791\Node1\Link Quality
Link Quality
AI0
AI1
AI2
AI3
AI 1 AMPS
AI 2 AMPS
2
2
WSN timestamp
MAESTRO_R_4.lvproj/My Computer

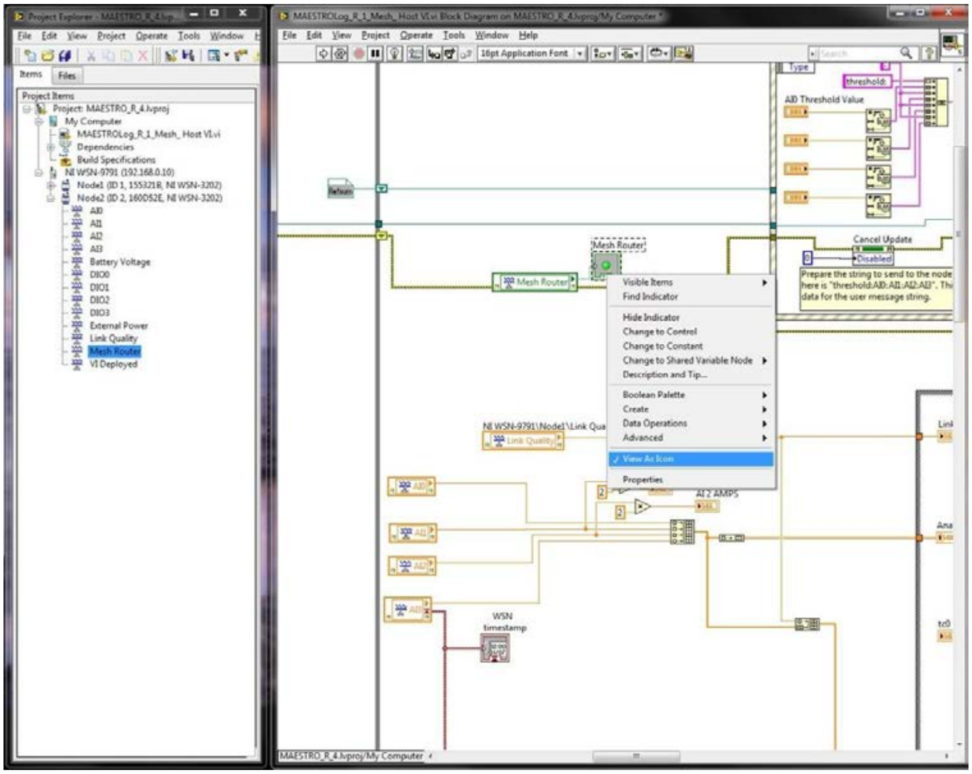

Project Explorer - MAESTRO_R_4.lvp...
File Edit View Project Operate Tools Window
Items Files
Project Items
Project: MAESTRO_R_4.lvproj
My Computer
MAESTROLog_R_1_Mesh_ Host VI.vi
Dependencies
Build Specifications
NI WSN-9791 (192.168.0.10)
Node1 (ID 1, 155321B, NI WSN-3202)
Node2 (ID 2, 160D52E, NI WSN-3202)
AI0
AI1
AI2
AI3
Battery Voltage
DIO0
DIO1
DIO2
DIO3
External Power
Link Quality
Mesh Router
VI Deployed
MAESTROLog_R_1_Mesh_ Host VI.vi Block Diagram on MAESTRO_R_4.lvproj/My Computer
File Edit View Project Operate Tools Window Help
16pt Application Font
Search
Type
threshold:
AI0 Threshold Value
Return
Cancel Update
Disabled
Prepare the string to send to the node here is "threshold:AI0:AI1:AI2:AI3". Thi data for the user message string.
Mesh Router
NI WSN-9791\Node1\Link Quality
Link Quality
AI0
AI1
AI2
AI3
AI 1 AMPS
AI 2 AMPS
2
2
WSN timestamp
Lin
Ana
tc0
MAESTRO_R_4.lvproj/My Computer

Begin to rewire the "error line" through the bottom portion of the "mesh router" input. We will then need to create an indicator for one of the outputs of the "mesh router" input. To do so, right click on the side arrow of the mesh router and a new window will appear. Navigate through the new window to create > indicator. This indicator will appear on the front panel of the program and is strictly used to verify working order of the mesh router.

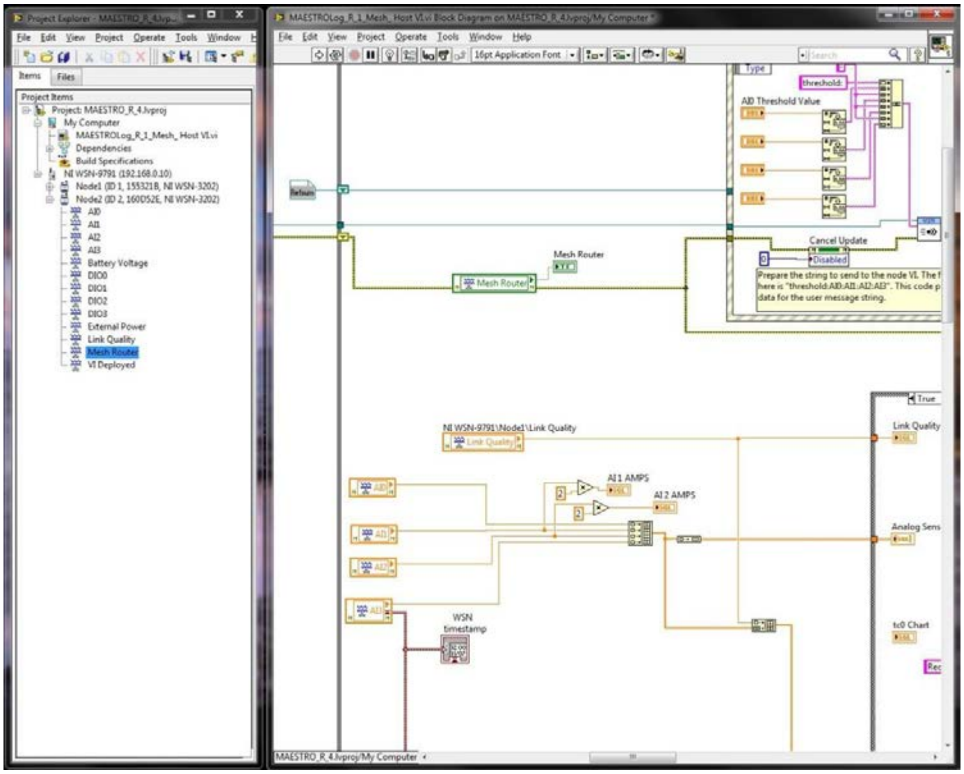




This next step is completely optional, but is done to save space of the block diagram and for consistency. Right-click on the newly created indicator icon and navigate towards the bottom of the screen and select "View as icon".

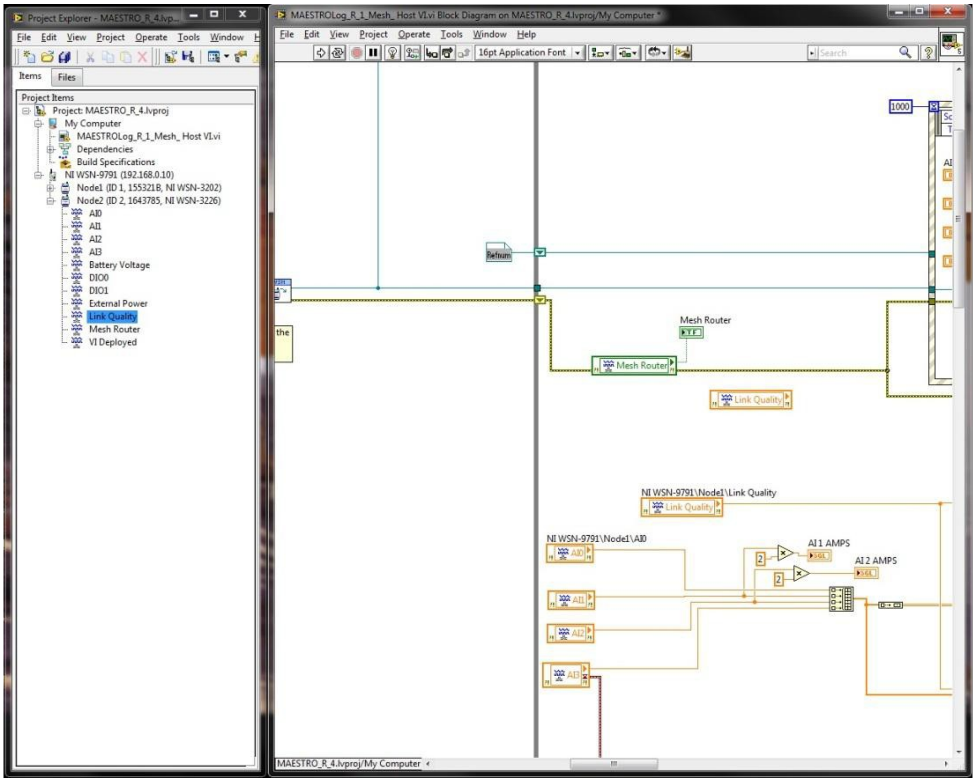


Prepare the string to send to the node here is "threshold:AI0:AI1:AI2:AI3". Th data for the user message string.

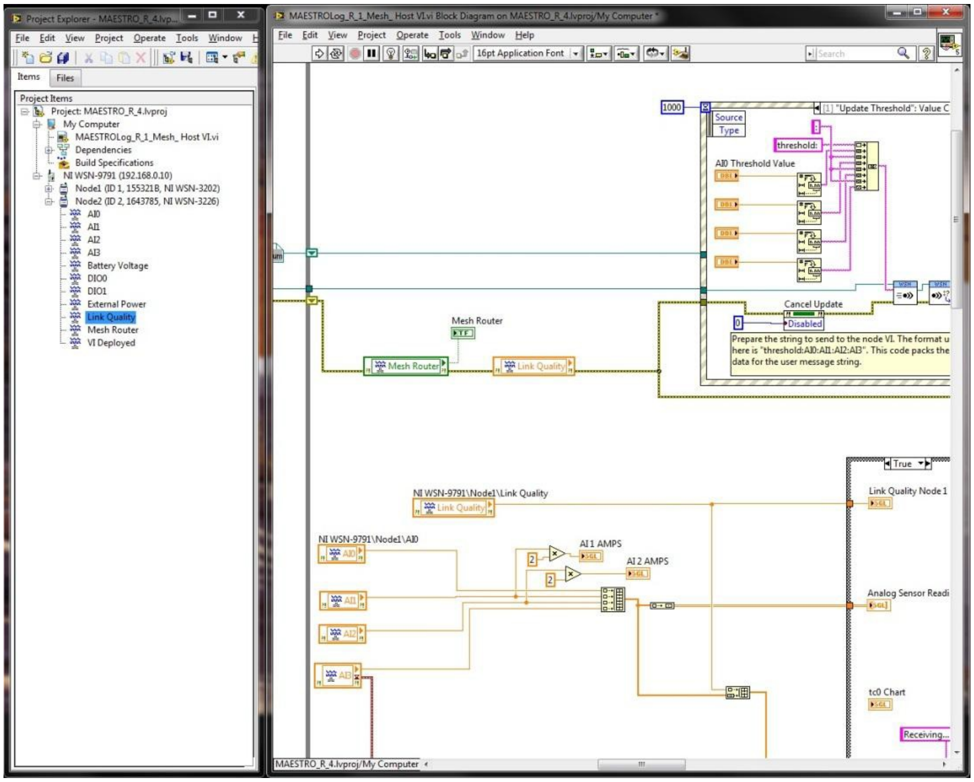


Prepare the string to send to the node VI. The f
here is "threshold:AI0:AI1:AI2:AI3". This code p
data for the user message string.

When installing the monitoring system, it may be necessary to verify the signal quality of the mesh router to ensure optimal placement for it. To do this, we will complete nearly the same steps as the mesh router. From the project explorer under the gateway portion, expand the tree diagram of the node you would like to use as a mesh router. Locate the "link quality" input of the node. Then proceed to click and drag it to the block diagram. Delete any existing wires/connections that the "link quality" input will need, specifically the "error line".

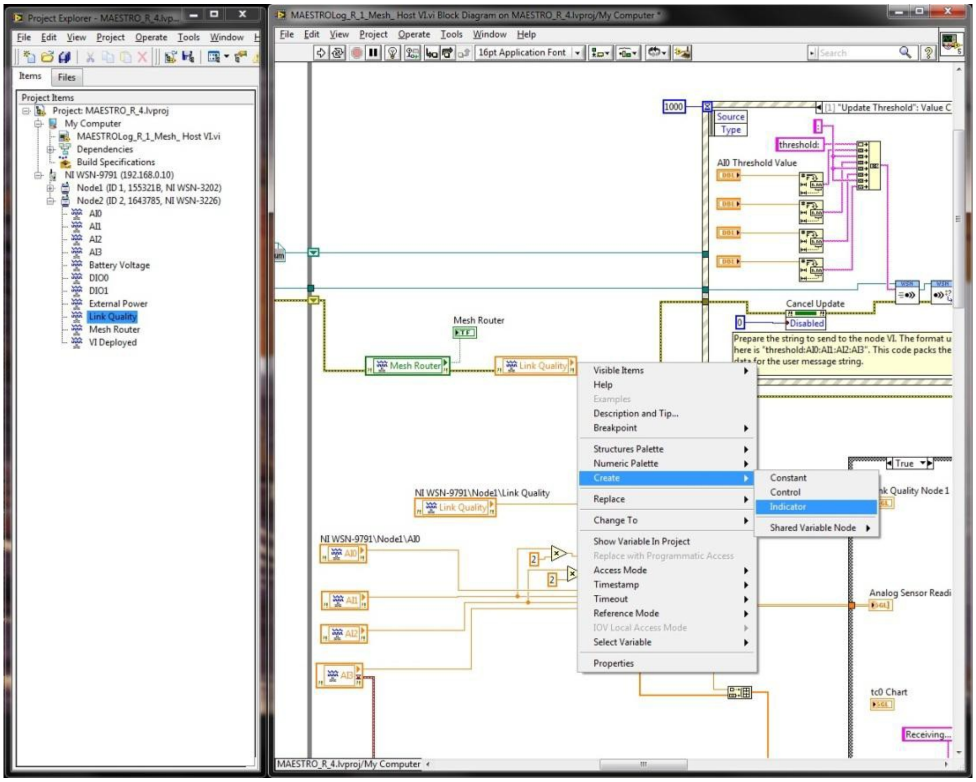


Begin to rewire the "error line" through the bottom portion of the "link quality" input.

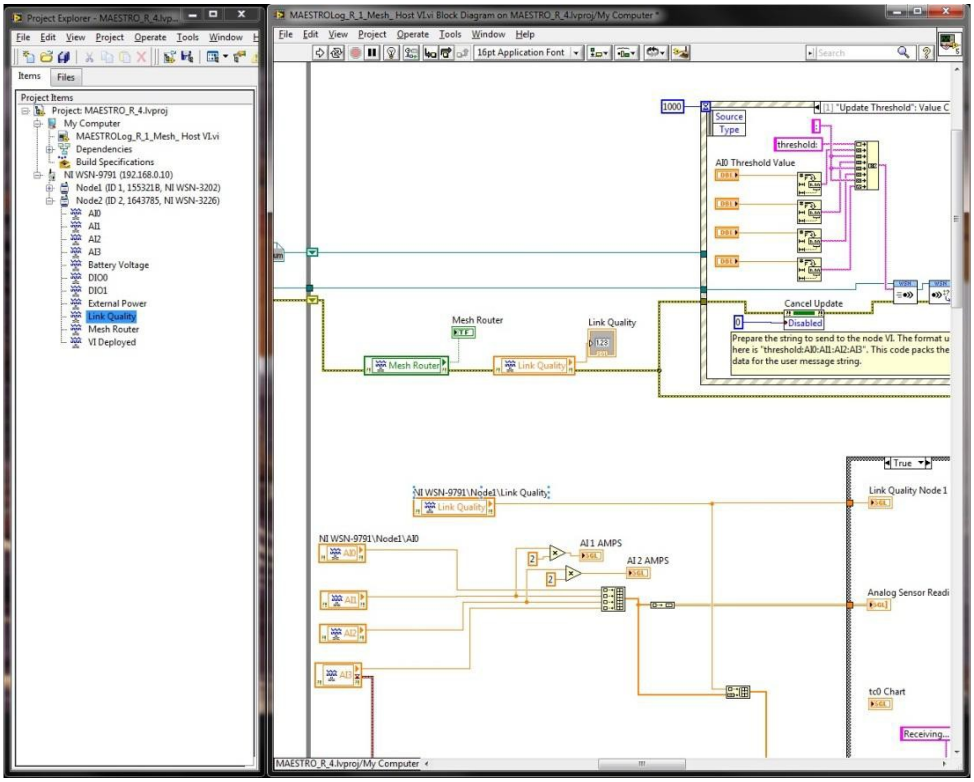


Prepare the string to send to the node VI. The format u
here is "threshold:AI0:AI1:AI2:AI3". This code packs the
data for the user message string.

We will then need to create an indicator for one of the outputs of the "link quality" input. To do so, right click on the side arrow of the link quality block and a new window will appear. Navigate through the new window to create > indicator. This indicator will appear on the front panel and display the signal strength of the mesh router.

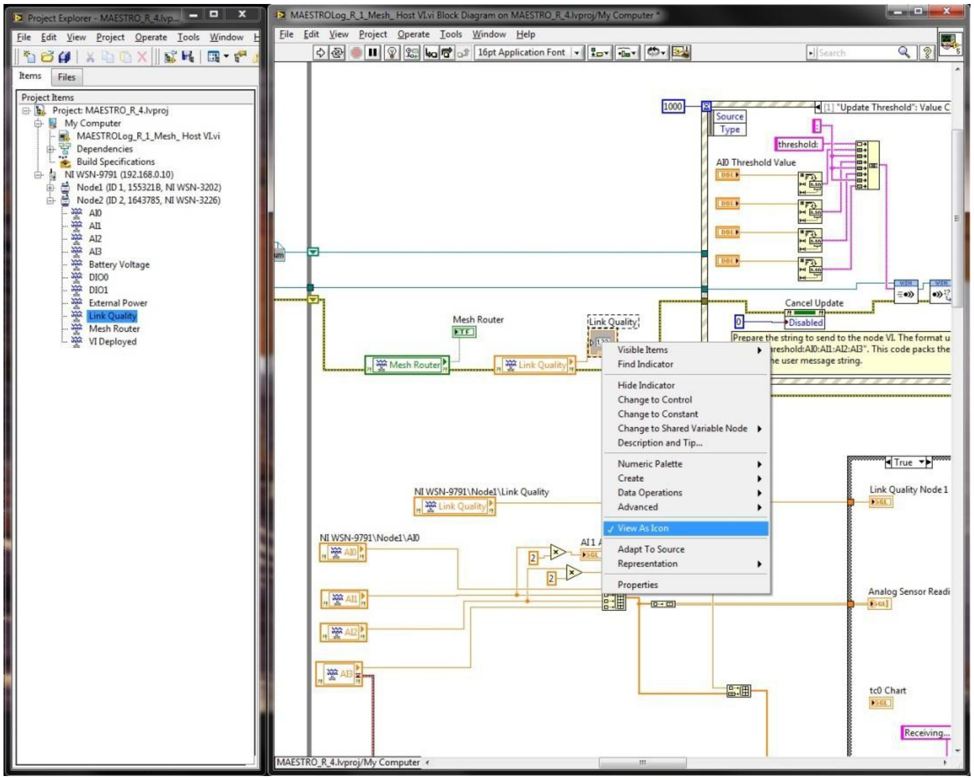


Prepare the string to send to the node VI. The format u here is "threshold:AI0:AI1:AI2:AI3". This code packs the data for the user message string.

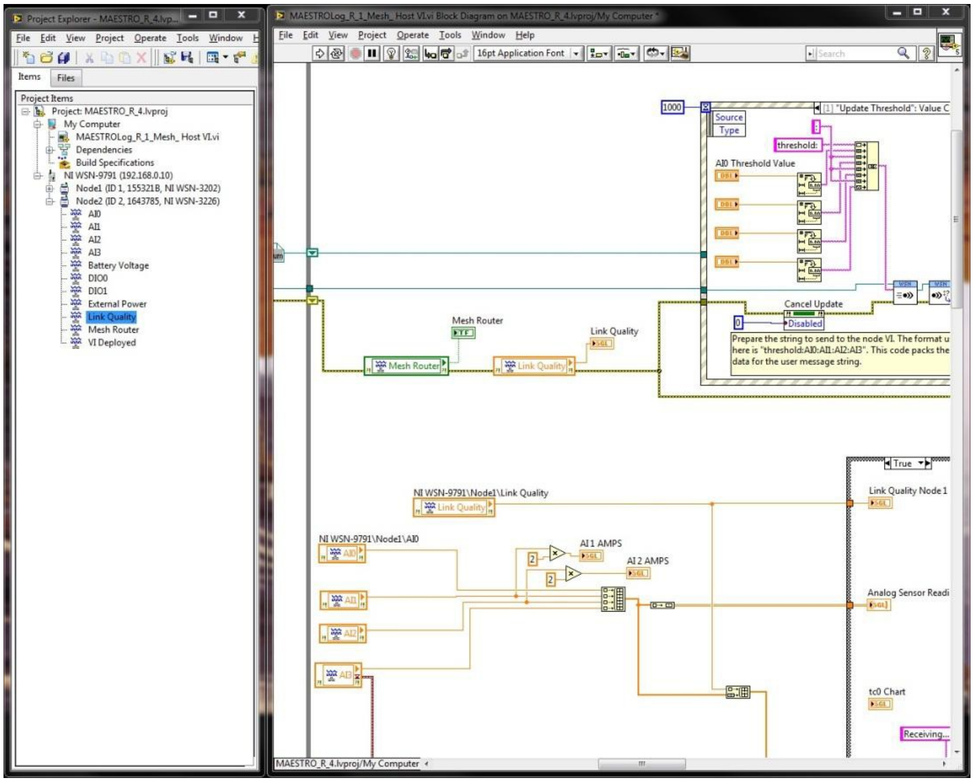


Prepare the string to send to the node VI. The format u here is "threshold:AI0:AI1:AI2:AI3". This code packs the data for the user message string.

This next step is completely optional, but is done to save space of the block diagram and for consistency. Right-click on the newly created indicator icon and navigate towards the bottom of the screen and select "View as icon".

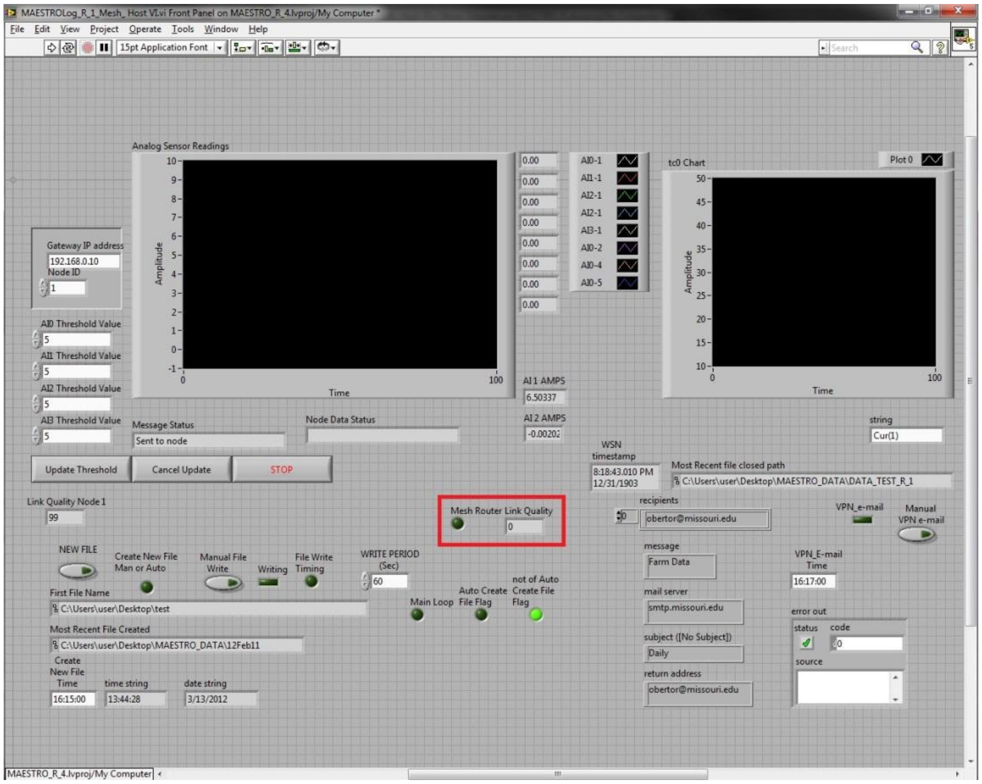


Prepare the string to send to the node VI. The format u
reshold:AI0:AI1:AI2:AI3". This code packs the
e user message string.



Prepare the string to send to the node VI. The format u
here is "threshold:AI0:AI1:AI2:AI3". This code packs the
data for the user message string.

The figure below displays the front panel with the two new indicators for the working operation and signal strength of the mesh router. In the figure, the red box shows the newly added indicators.



Gateway IP address
192.168.0.10
Node ID
1

AI0 Threshold Value
5
AI1 Threshold Value
5
AI2 Threshold Value
5
AI3 Threshold Value
5

Message Status
Sent to node
Node Data Status

AI1 AMPS
6.50337
AI 2 AMPS
-0.00202

string
Cur(1)

WSN timestamp
8:18:43.010 PM
12/31/1903
Most Recent file closed path
C:\Users\user\Desktop\MAESTRO_DATA\DATA_TEST_R_1

Link Quality Node 1
99

Mesh Router Link Quality
0

WRITE PERIOD (Sec)
60

First File Name
C:\Users\user\Desktop\test
Most Recent File Created
C:\Users\user\Desktop\MAESTRO_DATA\12Feb11

Create New File Time
16:15:00
time string
13:44:28
date string
3/13/2012

recipients
0
obertor@missouri.edu
message
Farm Data
mail server
smtp.missouri.edu
subject ([No Subject])
Daily
return address
obertor@missouri.edu

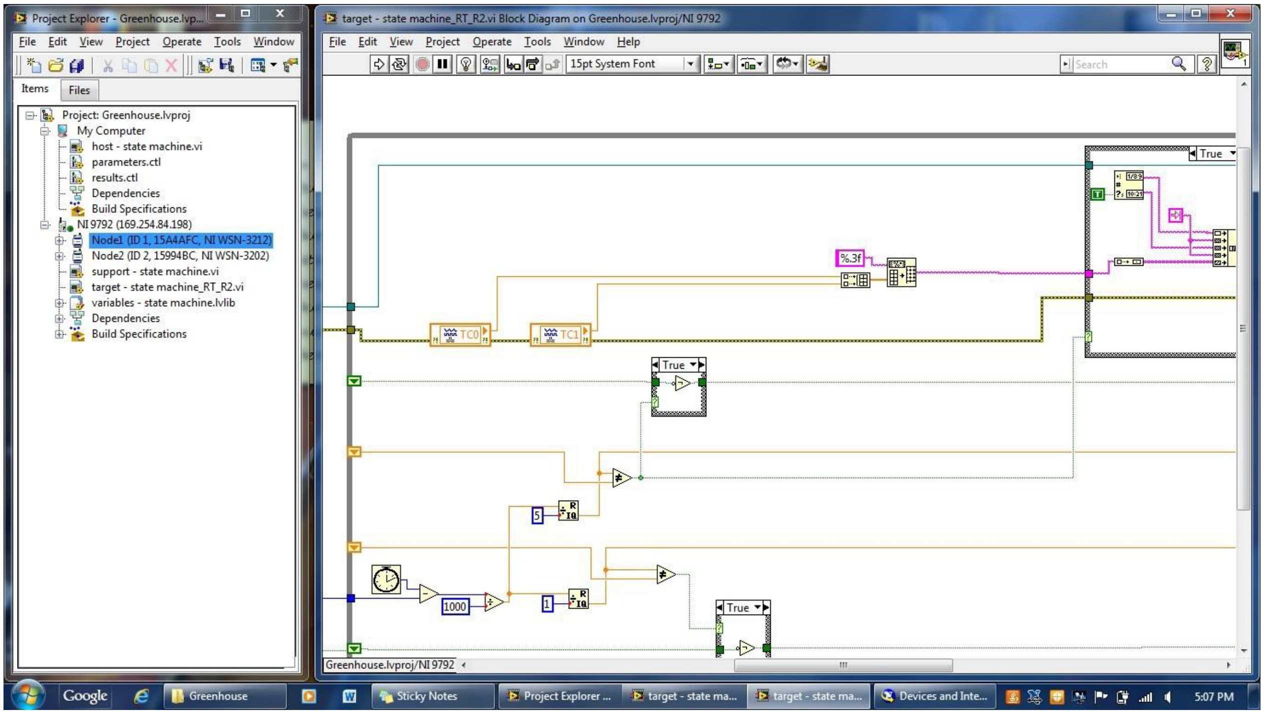
VPN_E-mail Time
16:17:00

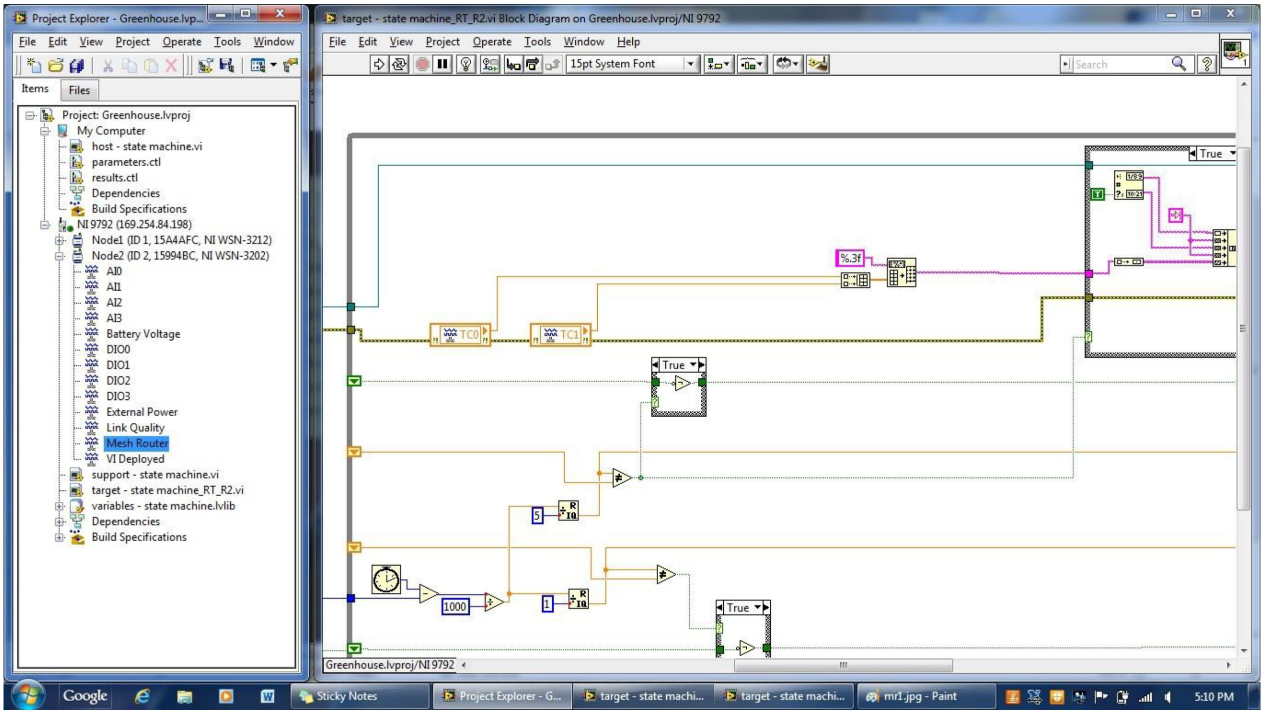
error out
status
✓
code
0
source

Adding A Mesh Router Through LabVIEW (NI-9792)

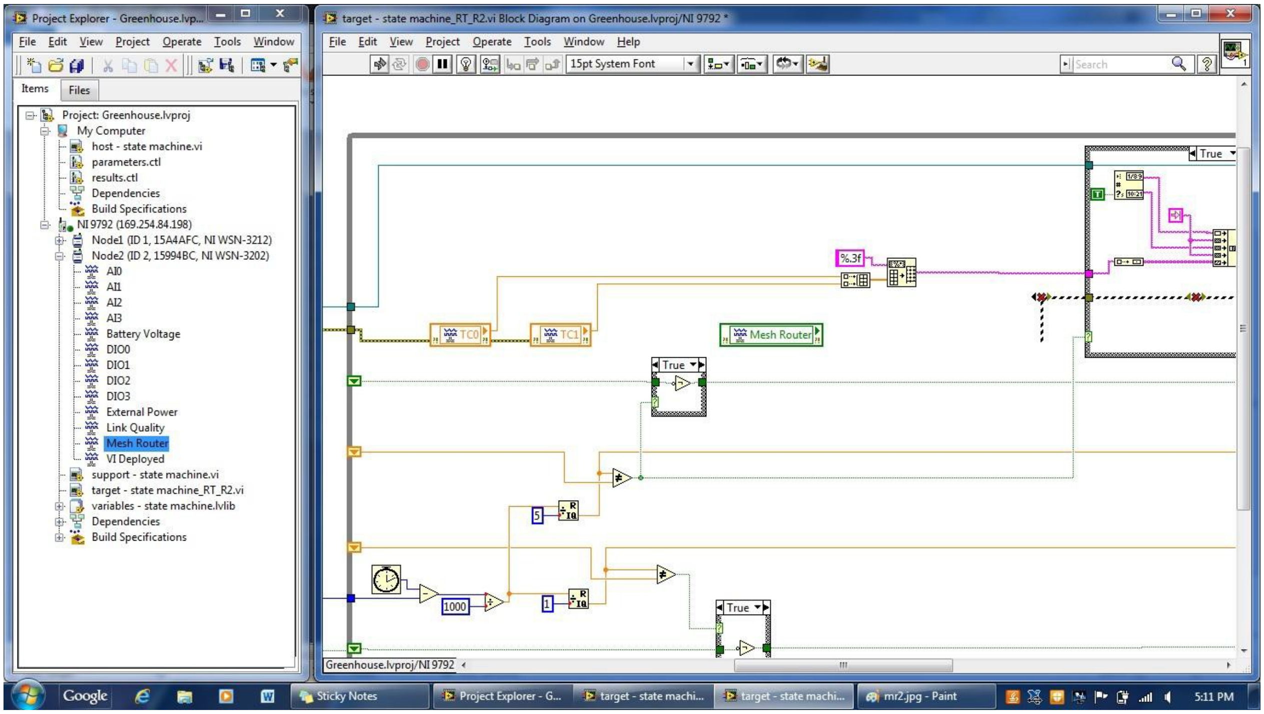
The next step (optional - depending on the geography of your area) is adding the mesh router to the project to be recognized by the gateway. It is important to realize as well that while the node is configured as a mesh router, it cannot measure any type of data. Additionally, a constant power supply is recommended as the mesh router is constantly powered and uses more power than a typical end node.

First, open the corresponding project you would like to add a mesh router to, along with the block diagram for measurements. From the project explorer under the gateway portion, expand the tree diagram of the node you would like to use as a mesh router. Locate the "mesh router" input of the node. The figures below show a basic instrumentation program with two inputs/outputs, TC0 and TC1. For this example, we will be adding node #2 as a mesh router to the program.

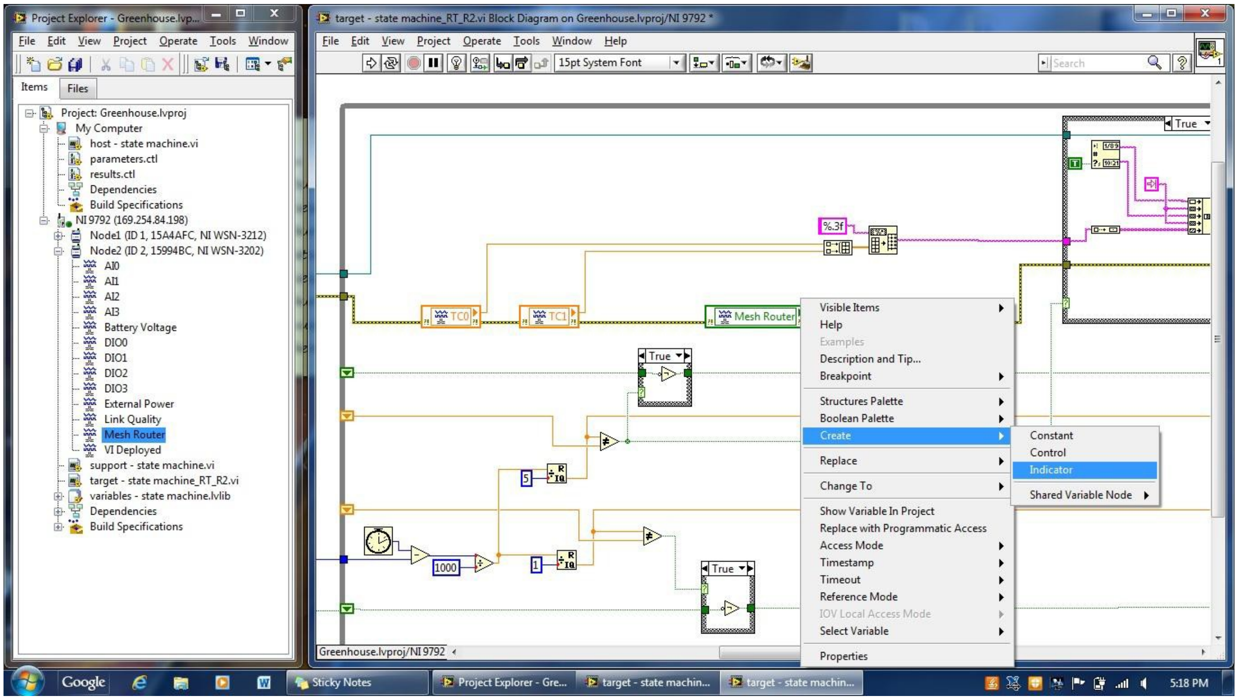




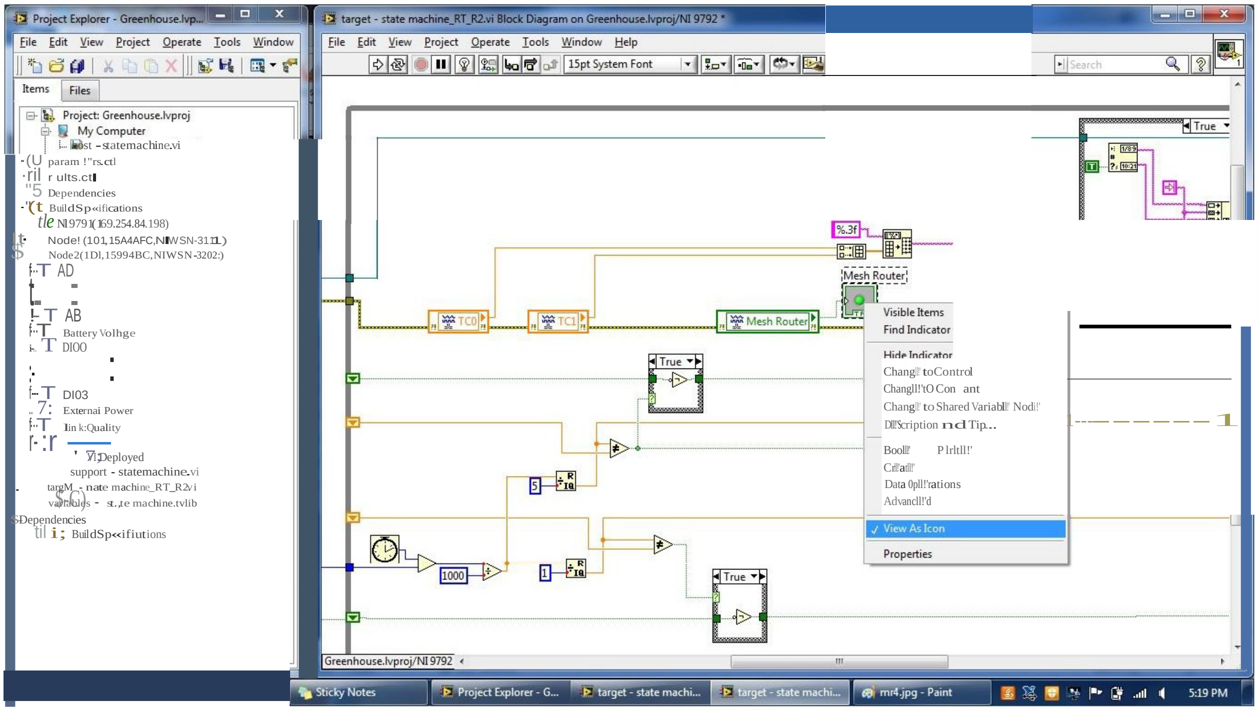
Then proceed to click and drag the "Mesh Router" input to the block diagram, just as you would do for adding an input for a end node (i.e. AI0, AI1, AI2, etc.). Also, delete any existing wires/connections that the "mesh router" input will need, specifically the "error line".

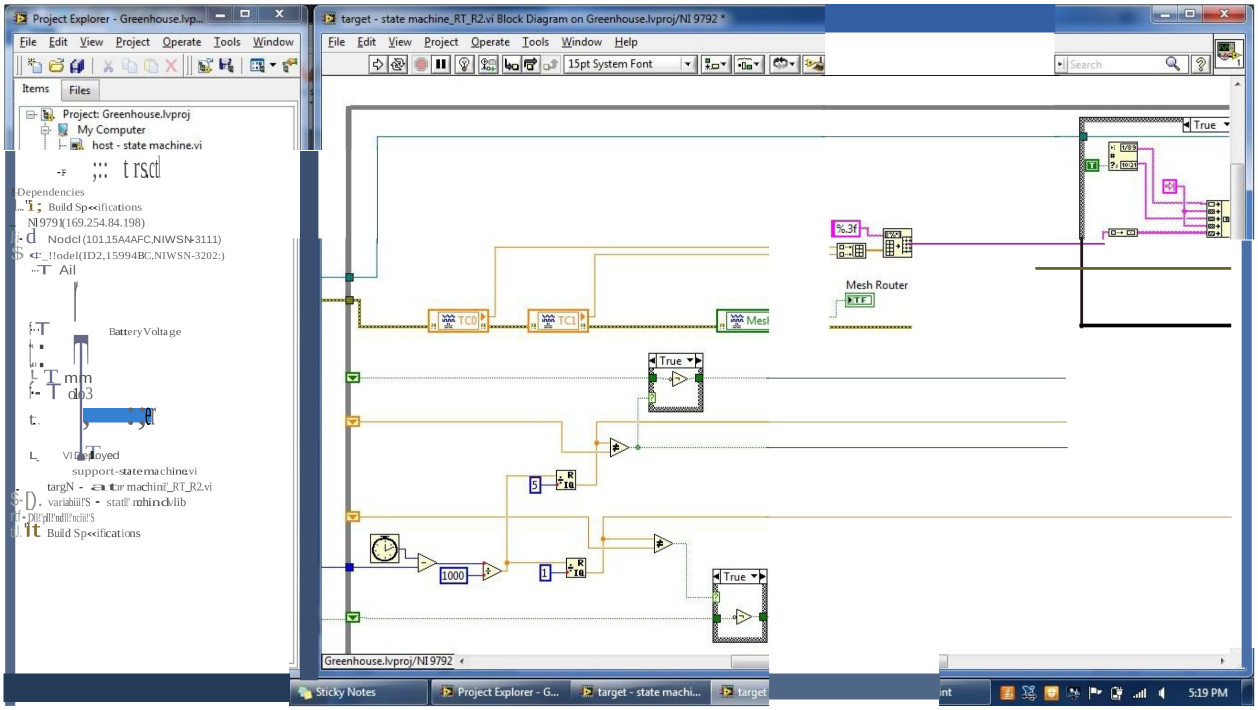


Begin to rewire the "error line" through the bottom portion of the "mesh router" input. We will then need to create an indicator for one of the outputs of the "mesh router" input. To do so, right click on the side arrow of the mesh router and a new window will appear. Navigate through the new window to create > indicator. This indicator will appear on the front panel of the program and is strictly used to verify working order of the mesh router.

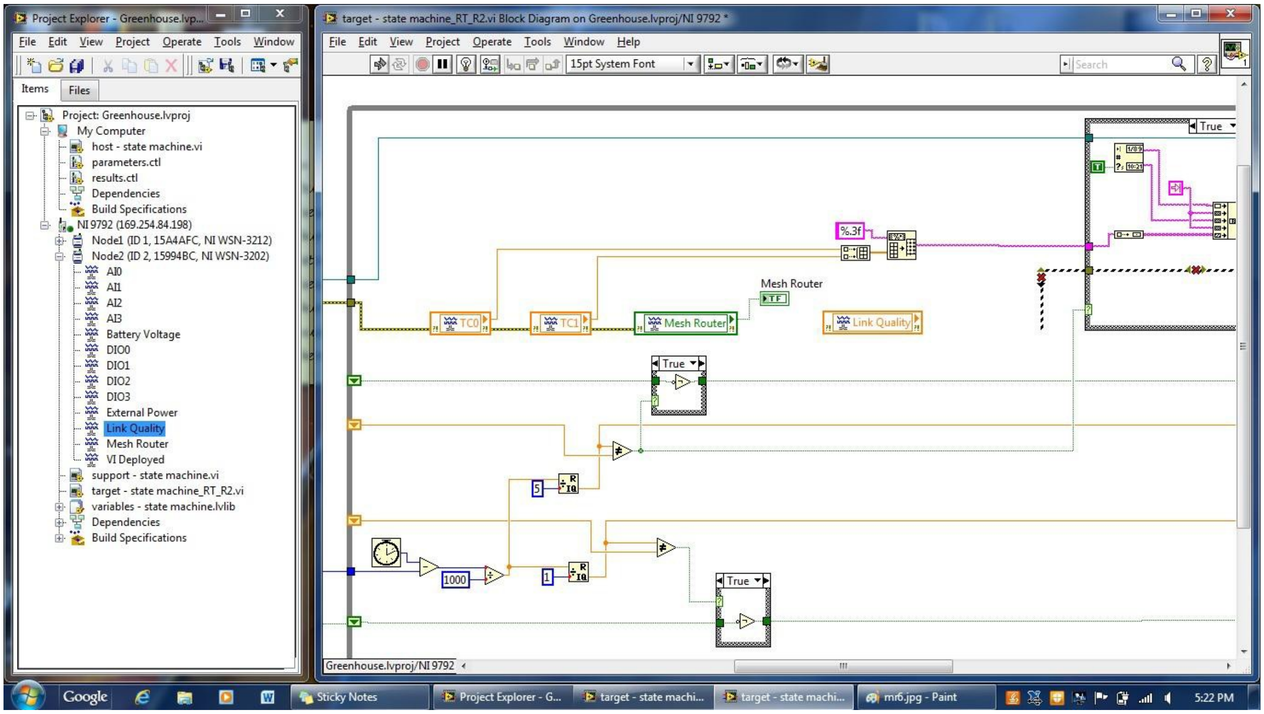


This next step is completely optional, but is done to save space of the block diagram and for consistency. Right-click on the newly created indicator icon and navigate towards the bottom of the screen and select "View as icon".

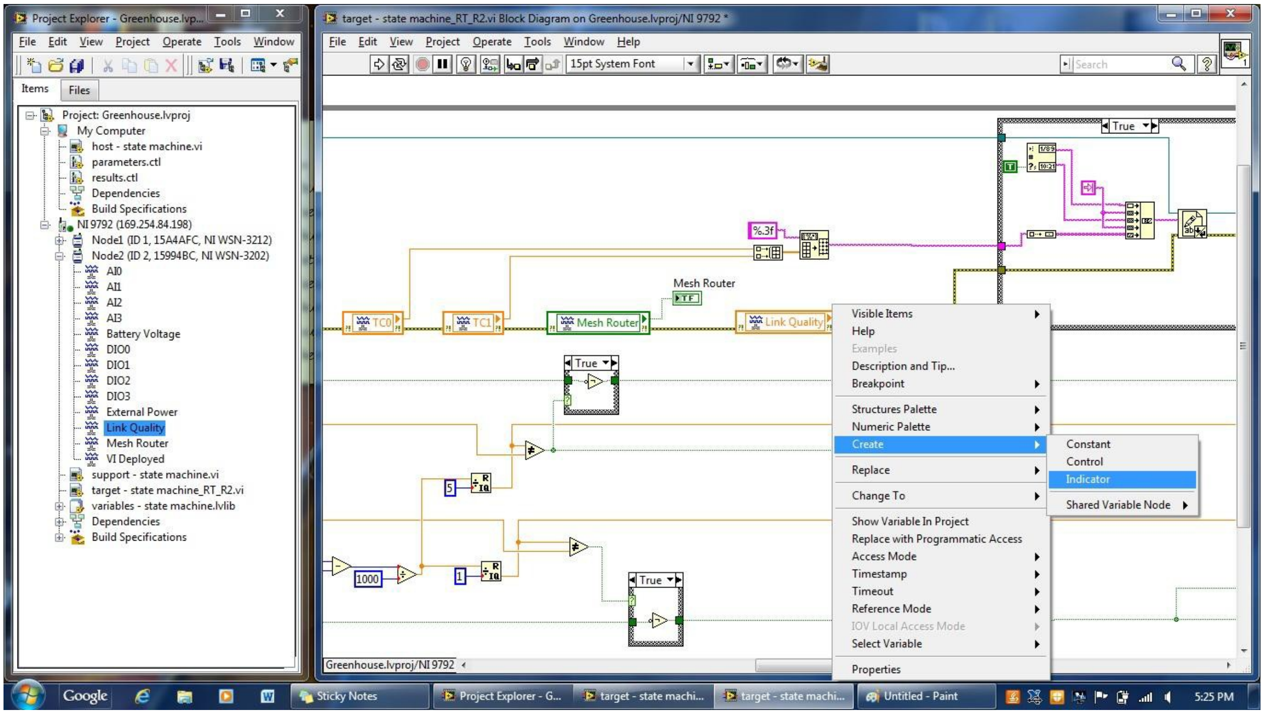


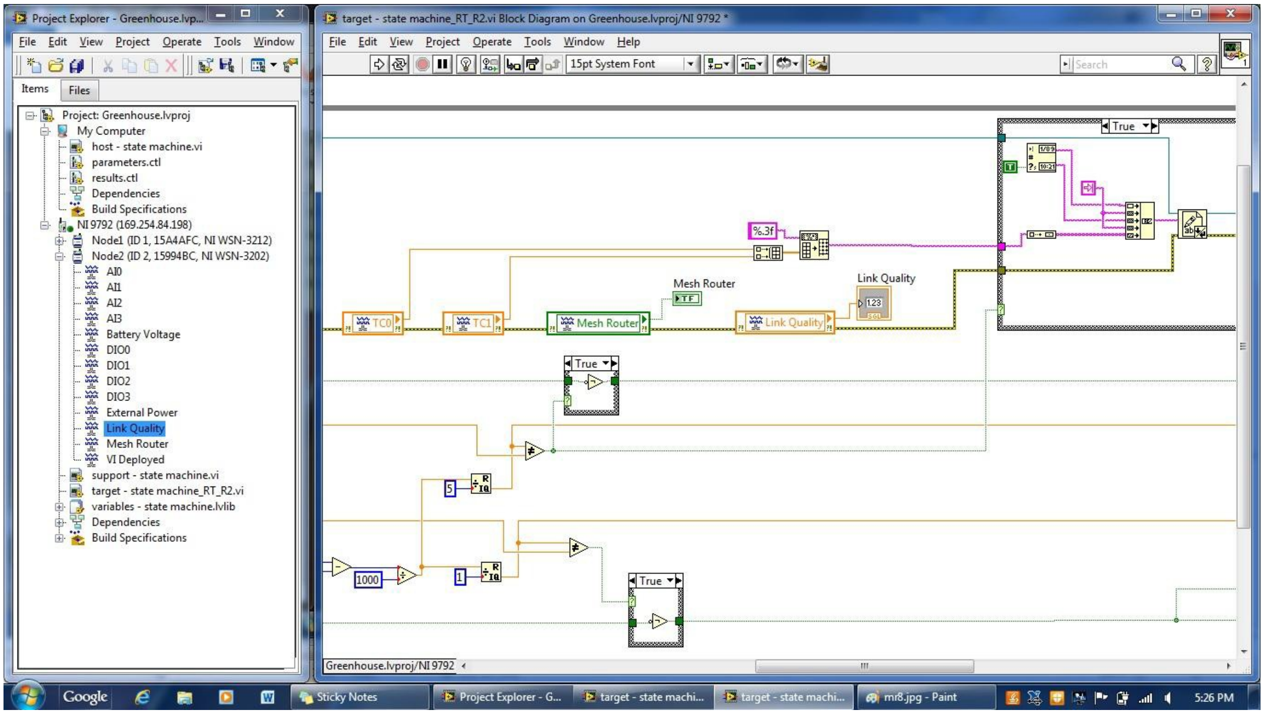


When installing the monitoring system, it may be necessary to verify the signal quality of the mesh router to ensure optimal placement for it. To do this, we will complete nearly the same steps as the mesh router. From the project explorer under the gateway portion, expand the tree diagram of the node you would like to use as a mesh router. Locate the "link quality" input of the node. Then proceed to click and drag it to the block diagram. Delete any existing wires/connections that the "link quality" input will need, specifically the "error line".

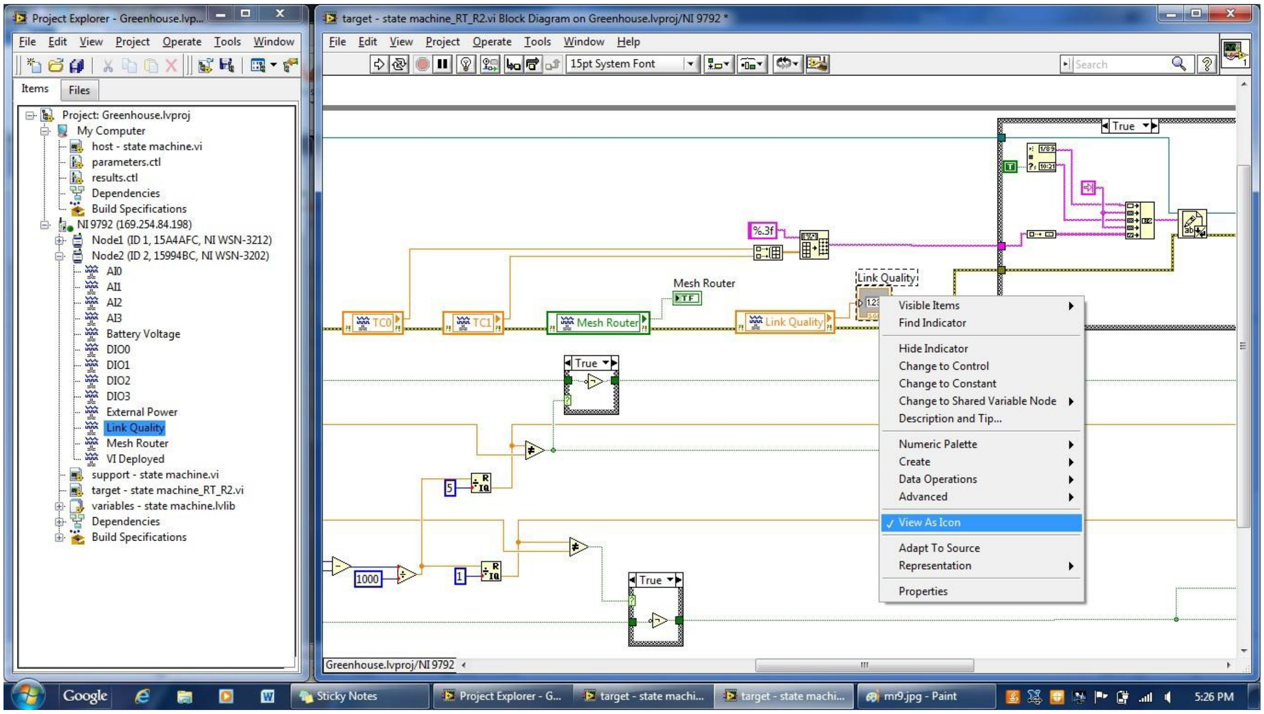


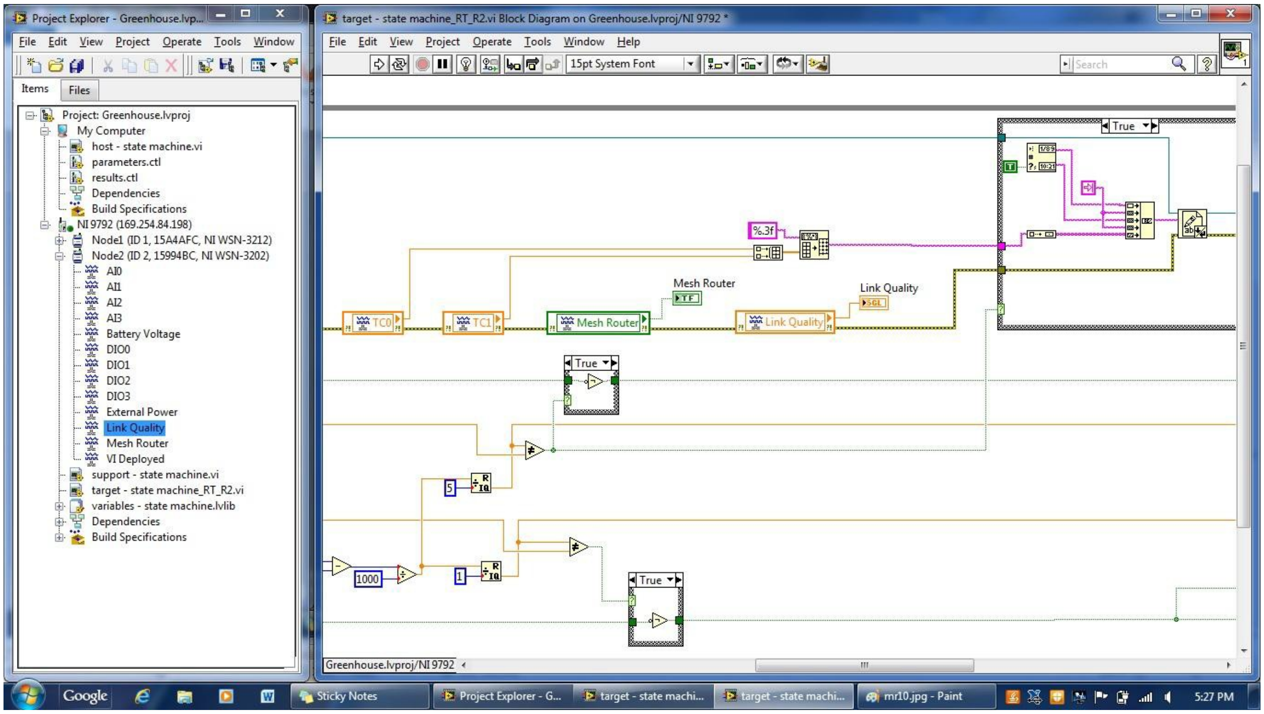
Begin to rewire the "error line" through the bottom portion of the "link quality" input. We will then need to create an indicator for one of the outputs of the "link quality" input. To do so, right click on the side arrow of the link quality block and a new window will appear. Navigate through the new window to create > indicator. This indicator will appear on the front panel and display the signal strength of the mesh router.



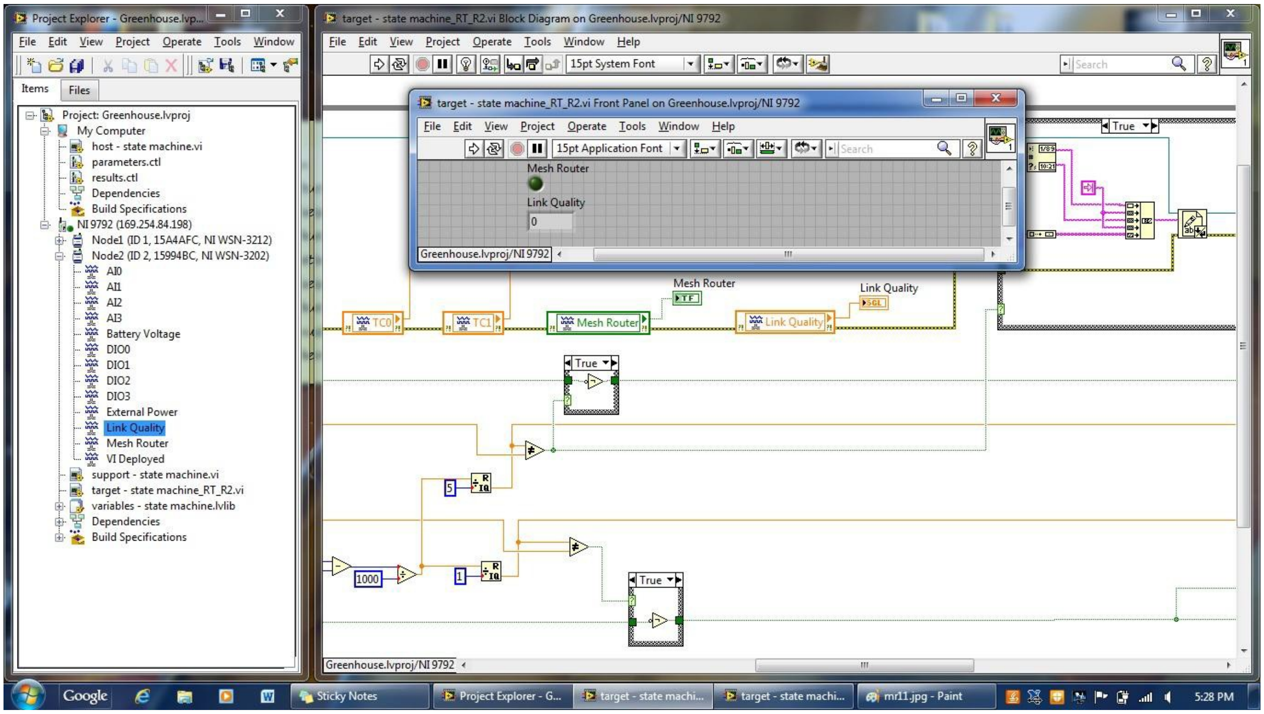


This next step is completely optional, but is done to save space of the block diagram and for consistency. Right-click on the newly created indicator icon and navigate towards the bottom of the screen and select "View as icon".



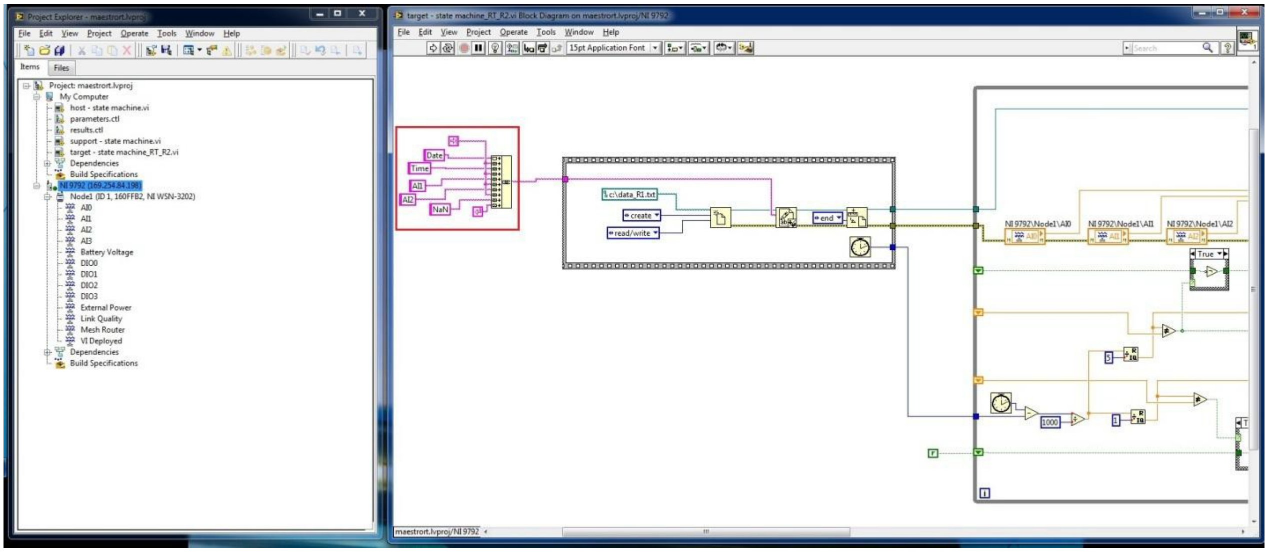


The figure below displays the front panel with the two new indicators for the working operation and signal strength of the mesh router.

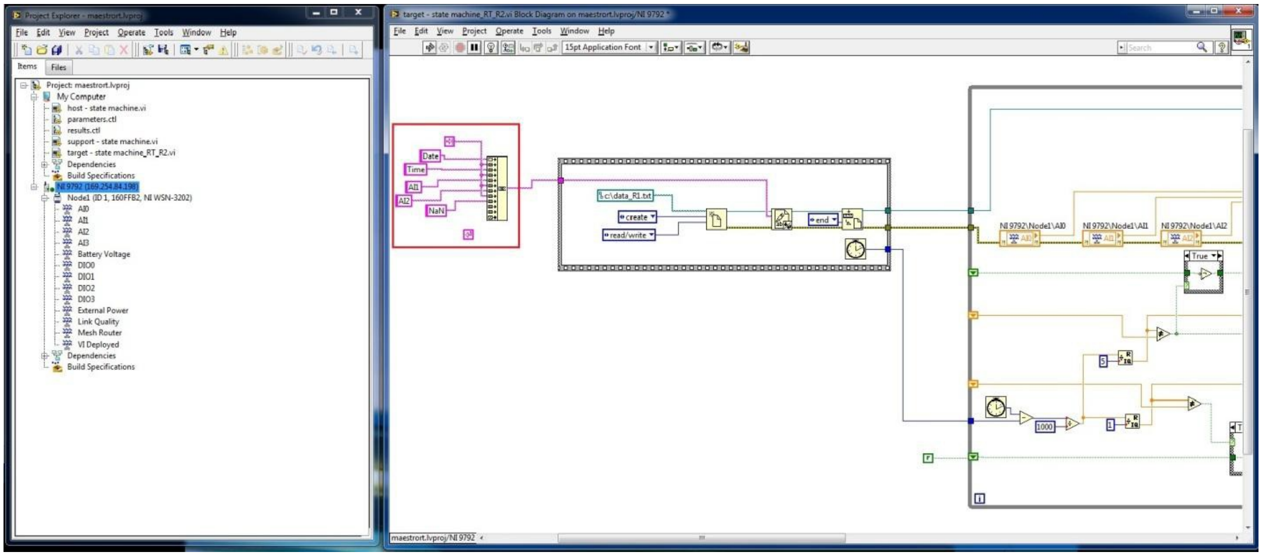


Editing the Data File’s Titles/Headings

If the number of inputs to a program is changed, this step will always be necessary. Failure to do so will result in data not appropriate to the data file’s heading, or extra data with no/extra headings. The first step to modifying the data file’s heading is to locate it on your block diagram. For our block diagram, it is located on the left side of the diagram which is highlighted by the red box in the figure below.

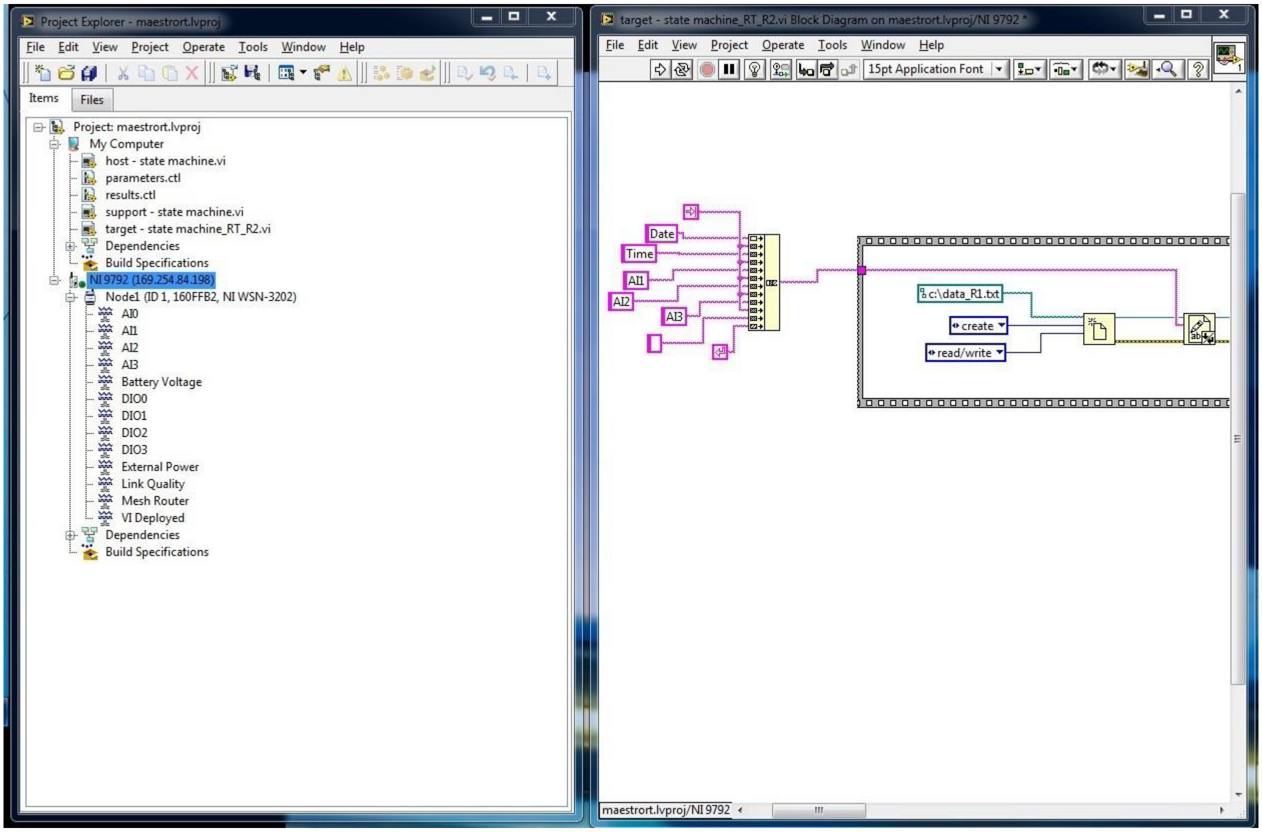


The output strings “date” and “time” will remain unchanged, but now that we have more inputs we will need to add another output string. To add the “AI2” output, we will need to modify the program’s array builder which is highlighted in the figure below. To modify this, select the Position/Size/Select tool and hover over the bottom of the build array structure. The tool will then physically change to a double arrow, or “↨”. Since we desire more outputs for the build array, click and pull down on the structure for the desired number of outputs. For every output string, we will need the build array structure to expand by two. The reason for this is there must be a tab constant wired to create new columns for the related data.

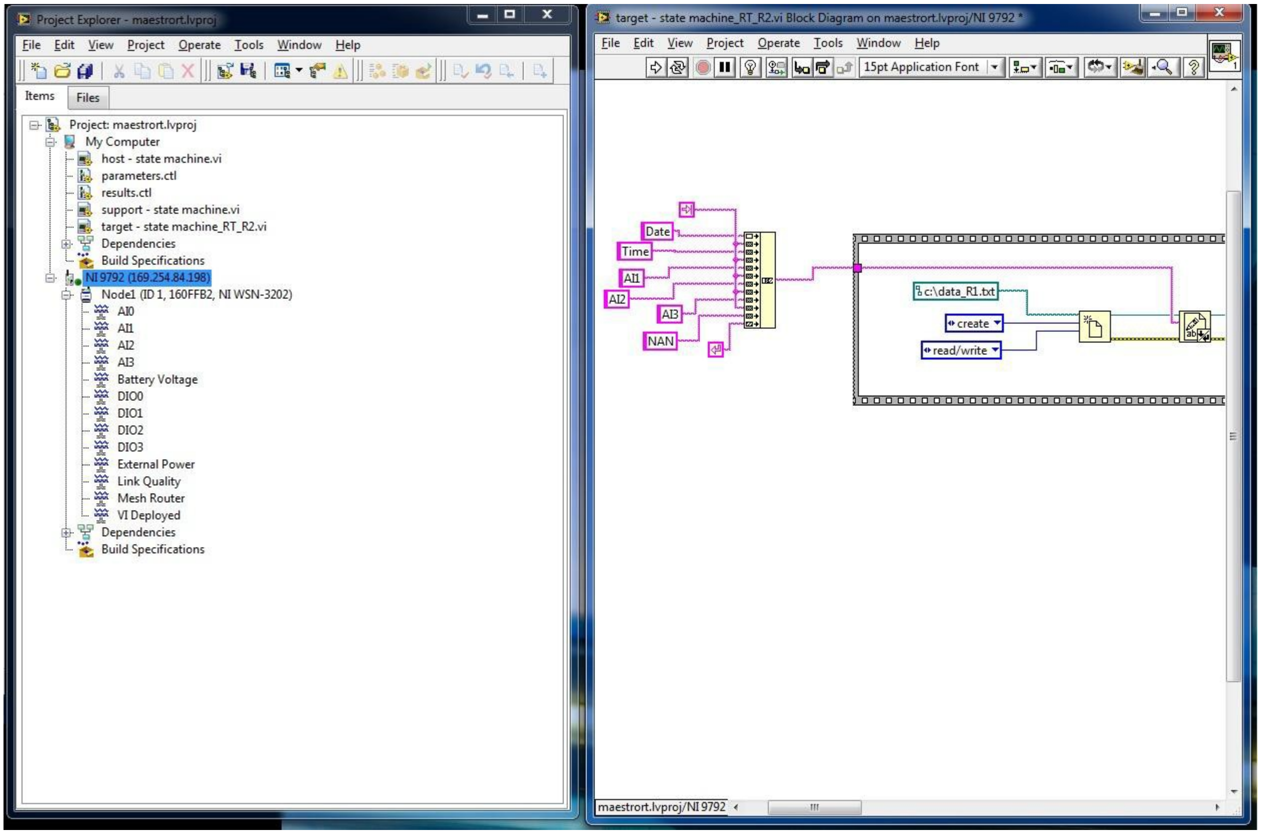


When completing this task, it is best to delete wires and rewire them instead of moving wires around. Wires may become hidden behind structures and lead to configurations being wired into the same element causing errors. After expanding the build array structure, navigate to the functions palette at the top of the block diagram Operate > Function Palette. Then navigate to Programming > String > String Constant and drag the function to the block diagram.

Begin to wire the tab constant for every other output string and ending the tab constant until the last output as shown below. Then begin to wire in the new string array and finish the structure with the end tab constant.

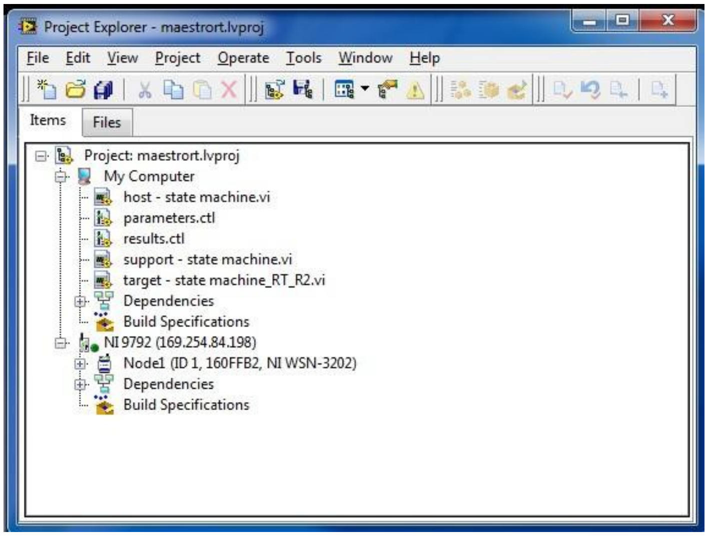


If you need to change the string titles, select the "edit text" tool and click on the appropriate string you would like to change. After entering your desired text, select the check mark in the upper left corner to confirm your changes. Below displays the finished product for the correct number of outputs needed for a program designed for three inputs.

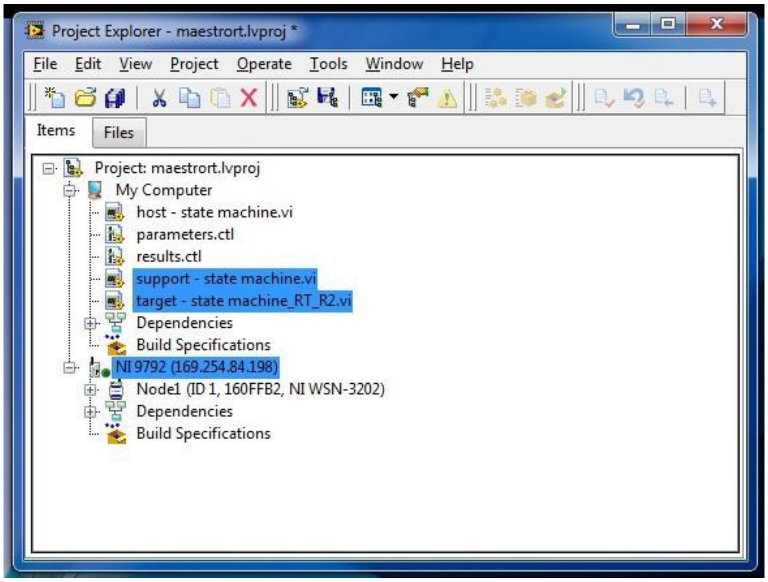


Adding Necessary Programs to NI-9792

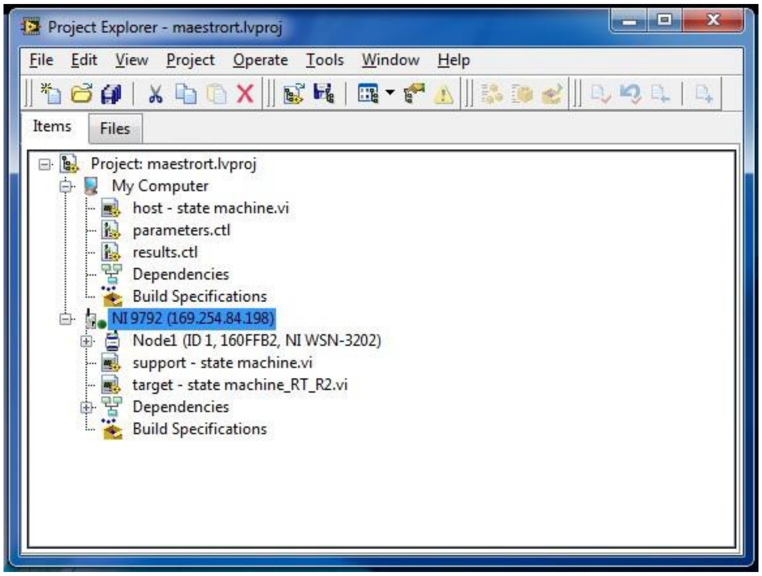
After successfully building your program files in LabVIEW, you must then transfer them to the gateway. However, this step is ONLY necessary if planning on creating a real-time project. In this example, the files being transferred are: “support – state machine.vi” and “target – state machine_RT_R2.vi”. Below serves as an example of a gateway that is being setup for real- time project without the necessary programs.



As seen above, the files needed to be transferred are in the “My Computer” section and need to be moved to the “NI 9792 (169.254.xx.xxx) location. To move these files, simultaneously hold the “ctrl” key and select all the files for transfer to the gateway. Your files will be highlighted in a blue area around the text of the files. While the all the needed files are highlighted, click and drag the files to “NI 9792 (169.254.xx.xxx)”. The text of the “NI 9792 (169.254.xx.xxx)” will also become highlighted (indicating selection), and then release your mouse’s button. The figure below is to serve as an example of the highlighted files and new desired location of the files.

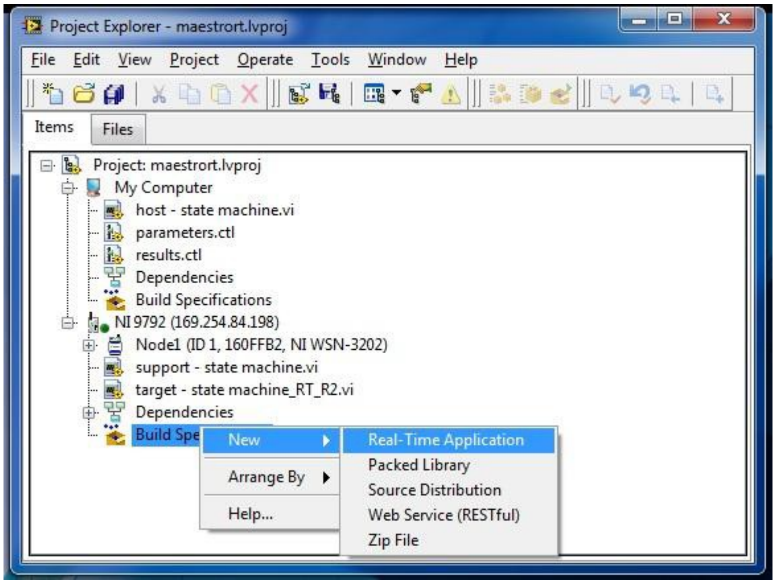


Once completing this step, the files will be then transferred into the “NI 9792 (169.254.xx.xxx)” location and may begin towards making a real-time application. As seen below, the files are now in the desired location.

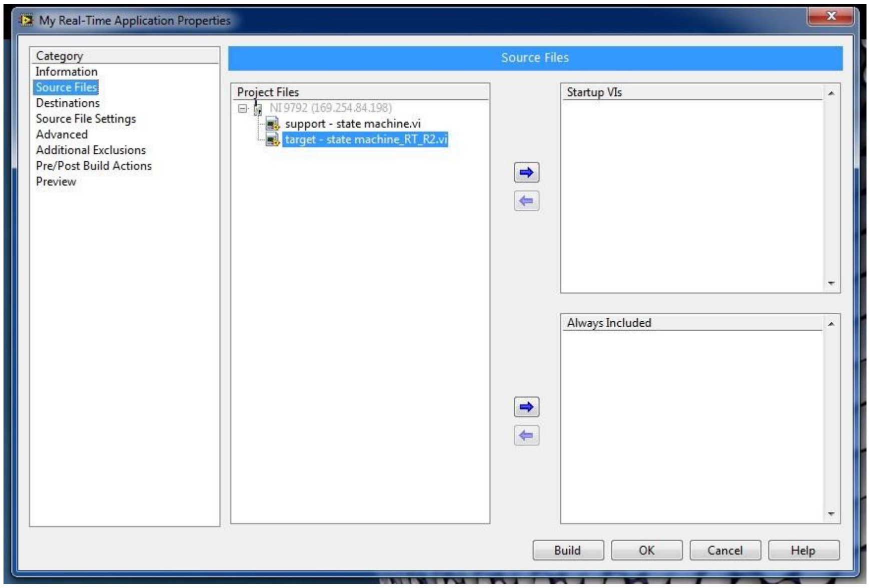


Setting Up NI-9792 for Real-Time Application

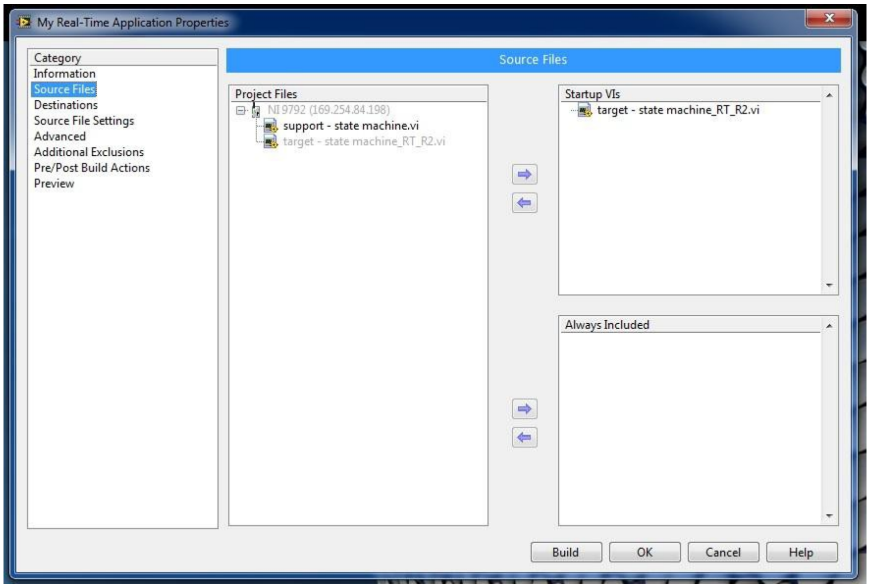
After the necessary files have been added, this begins the final steps for completing the gateway. For this step to be completed, maintain a connection with the gateway via Ethernet at all times. Disconnecting the gateway before completing this process can lead to errors, therefore it cannot be stressed enough to maintain a consistent connection. To begin creating a real-time application, open the project explorer and ensure the gateway is connected to the host. Under the gateway's drive, several files/options will be available, but we are only interested in the "build specifications" option. Right click on "build specifications", and navigate to new > real-time application.



A new window titled "My Real-Time Application Properties" will then be displayed with several categories on the left side that contain information, and general properties for the project. For this use, the only category being utilized is the "Source Files" option. As shown in the figure below, the files transferred to the gateway earlier will be displayed under "Project Files" in the "Source Files" category. For this example, the main program for the data acquisition is the "target – state machine_RT_R2.vi" file and will serve as the startup VI for the gateway.

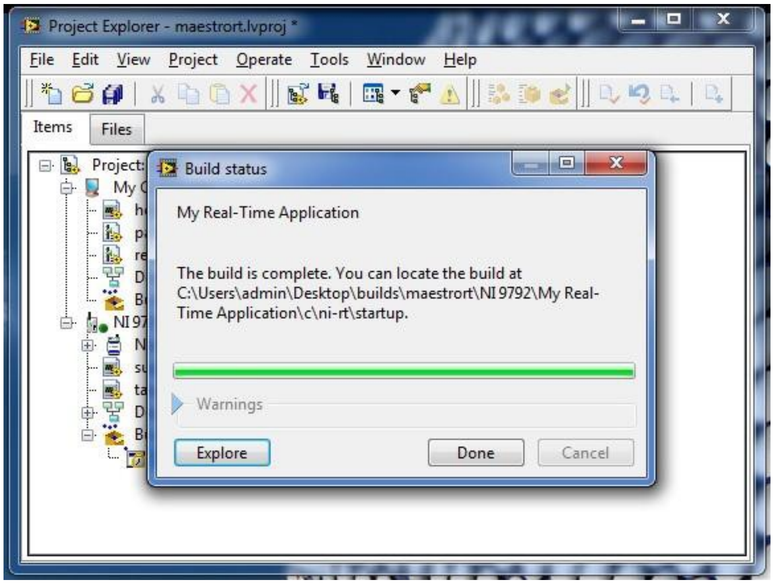


To move the file as the Startup VI on the gateway, select the file desired under "Project Files" and select the arrow pointing to the right. After completing this step, the file will be located under the Startup VIs and then select the "Build" option at the bottom of the window.



Note: In this example, we will maintain all other options set as default, but for your application you may change those options for your particular needs.

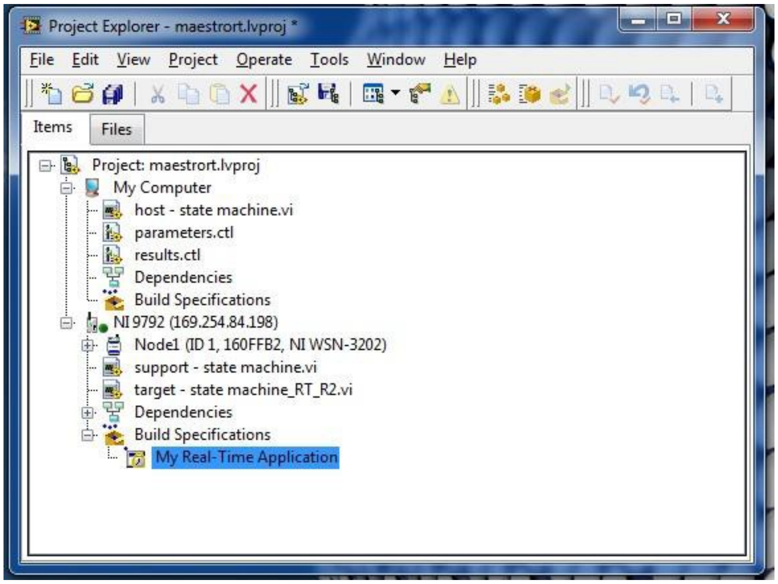
After selecting the "Build" option, a progress bar of the build status will display and the computer will begin to apply the program(s) to the gateway for data acquisition. Once the program is finished applying to the gateway, select the done option as shown below.



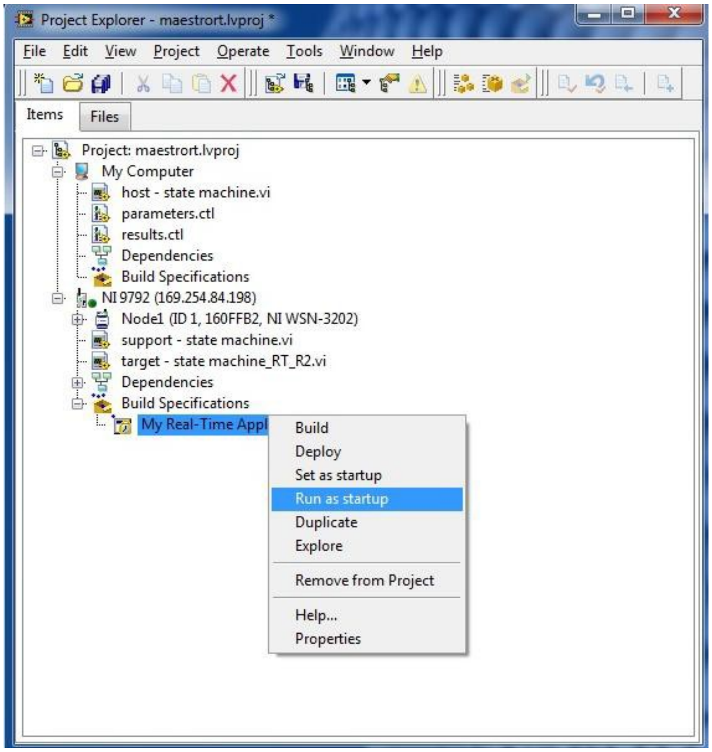
My Real-Time Application

The build is complete. You can locate the build at C:\Users\admin\Desktop\builds\maestrort\NI 9792\My Real-Time Application\c\ni-rt\startup.

After the completion of building the real-time application, the project explorer will again be displayed along with the new addition of "My Real-Time Application" under the "Build Specifications". Depending on your use/needs for data acquisition, the gateway can be set where the startup VI runs as soon as the gateway is powered on. For this purpose, we will be setting the startup VI to run when powered on. Setting the VI to run on startup, right click on "My Real- Time Application" located under "Build Specifications" and select the "run as startup" option.



Project: maestrort.lvproj
- My Computer
  - host - state machine.vi
  - parameters.ctl
  - results.ctl
  - Dependencies
  - Build Specifications
- NI 9792 (169.254.84.198)
  - Node1 (ID 1, 160FFB2, NI WSN-3202)
  - support - state machine.vi
  - target - state machine_RT_R2.vi
  - Dependencies
  - Build Specifications
    - My Real-Time Application



To complete this process, the gateway will need to reboot. Do NOT remove power or disturb the connection to the gateway. The device will automatically reboot itself and upon restart the gateway will begin running the designated startup VI.

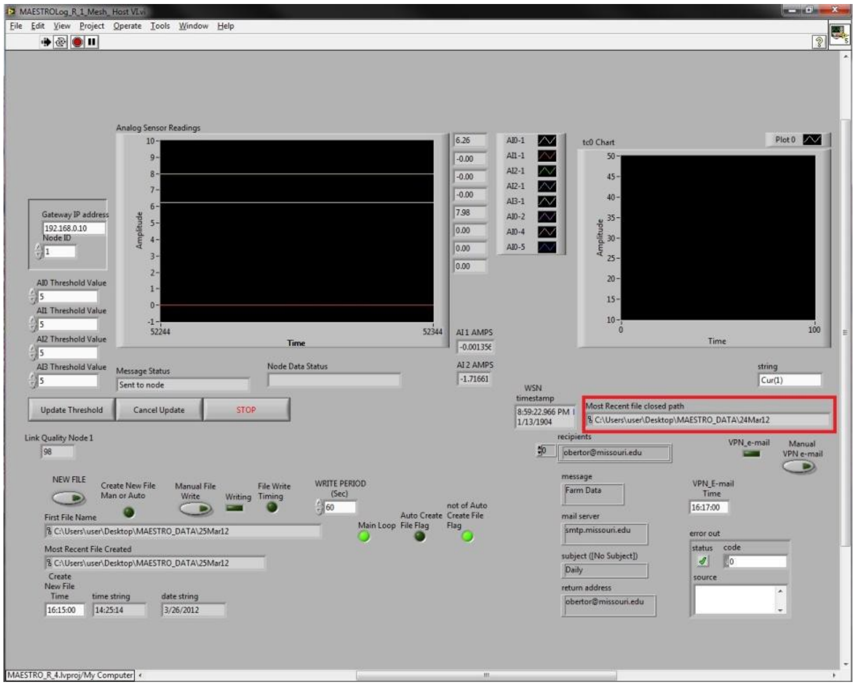
NOTE: If changes are made to your program such as adding nodes, making adjustments, etc, you must rebuild your startup VI and output it to the gateway every time. Failure to do so will yield older program files running instead of the newer/modified programs.

Accessing Files After Data Acquisition (NI-9791)

Since the NI-9791 requires a host, or computer. All the data and project files are saved onto the host's hard drive. No connection between the gateway and host are required for this process, therefore you may feel free to disconnect the gateway if necessary. To access and collect these files, we will need to determine the path of where they are saved onto the host's hard drive. Generally, you pre-set the path of the data files in the project explorer prior to data collection. However if you did not do this, the program is designed to automatically to save to the desktop.

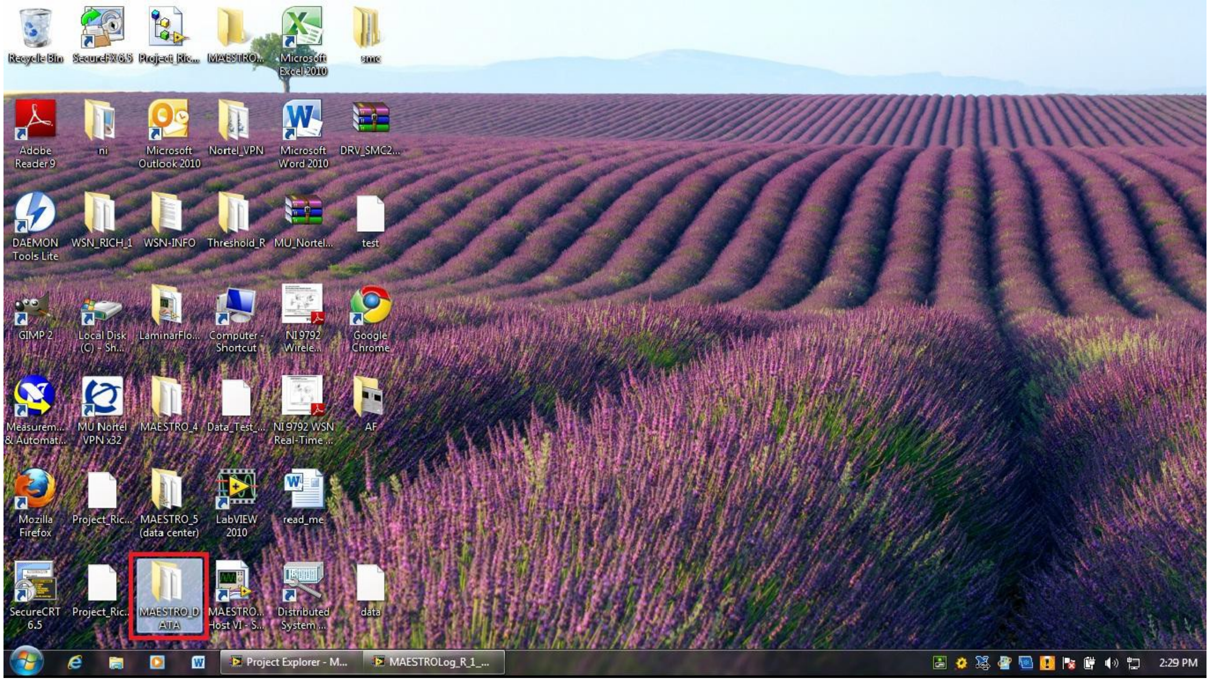
In the image below, the red highlighted box indicates the path of where the files are being saved. (i.e. C:\Users\user\Desktop\MAESTRO_Data\24Mar12). The last part of the path indicates the file name. While the second to last of the path indicates the name of the folder it is currently in. The middle term of the path indicates that folder is on the Desktop.

Note: this path will not be necessarily for your program, if you need further help, seek assistance from a professional.

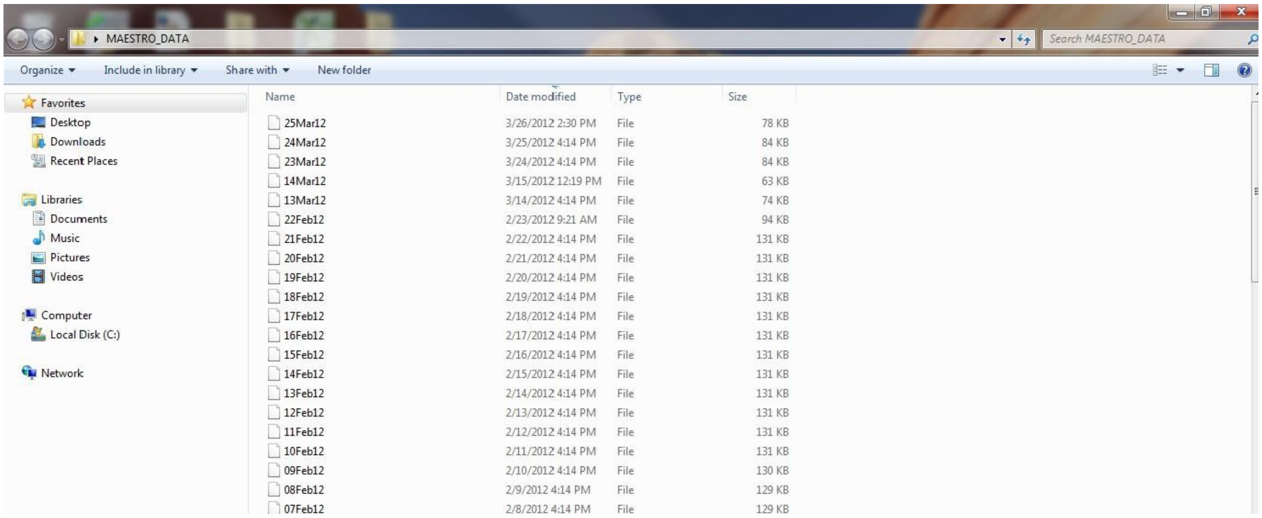


Gateway IP address: 192.168.0.10
Node ID: 1
AI0 Threshold Value: 5
AI1 Threshold Value: 5
AI2 Threshold Value: 5
AI3 Threshold Value: 5
Message Status: Sent to node
Node Data Status:
Link Quality Node 1: 98
6.26
-0.00
-0.00
-0.00
7.98
0.00
0.00
0.00
AI 1 AMPS: -0.00135€
AI 2 AMPS: -1.71661
WSN timestamp: 8:59:22.966 PM 1/13/1904
Most Recent file closed path: C:\Users\user\Desktop\MAESTRO_DATA\24Mar12
string: Cur(1)
recipients: 0 obertor@missouri.edu
message: Farm Data
mail server: smtp.missouri.edu
subject ([No Subject]): Daily
return address: obertor@missouri.edu
VPN_E-mail Time: 16:17:00
error out: status ✓ code 0 source
WRITE PERIOD (Sec): 60
First File Name: C:\Users\user\Desktop\MAESTRO_DATA\25Mar12
Most Recent File Created: C:\Users\user\Desktop\MAESTRO_DATA\25Mar12
Create New File Time: 16:15:00
time string: 14:25:14
date string: 3/26/2012

Looking at our file's path, we can determine that there is a folder on the Desktop named " MAESTRO_Data" that contains the file 24Mar12. We will then navigate to the Desktop and select the folder. The red highlighted box shows our folder we are looking for. Double click on the folder to open and access it.

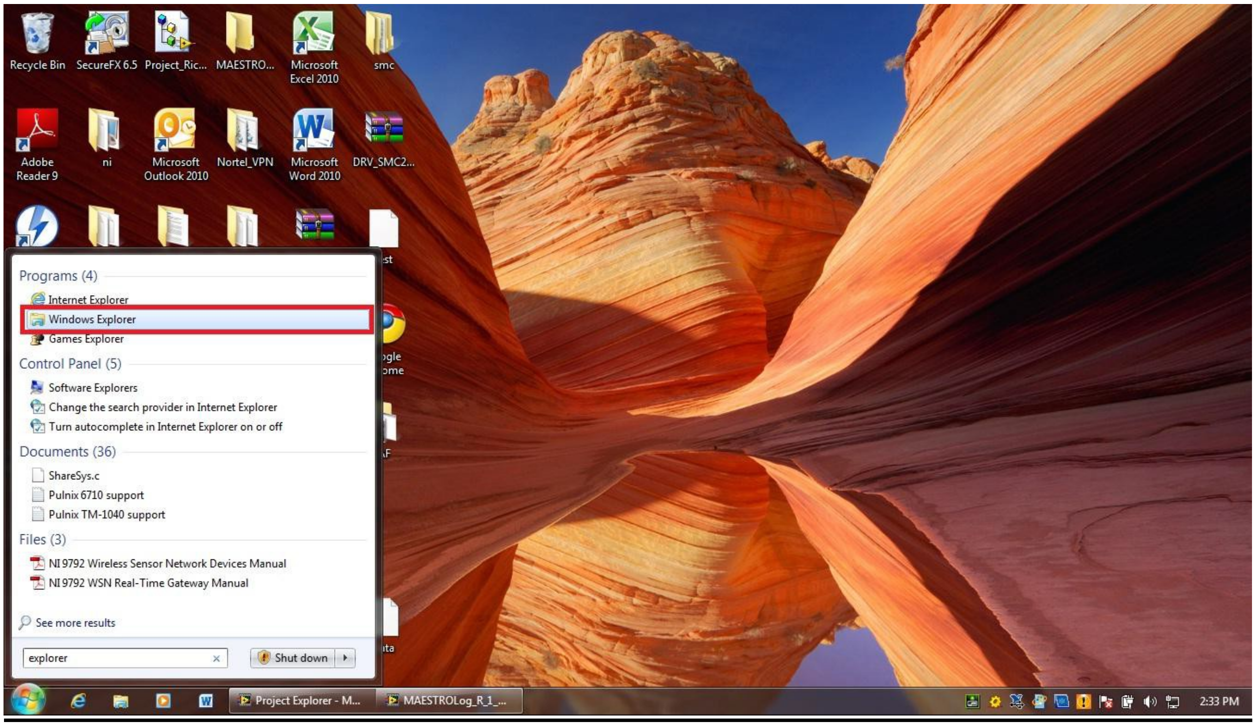


A new window will open displaying our data over a various amount of time. You may now select the file you would like to observe for data analysis. To do this, consult the section “Accessing the Output Data Written to Excel”.



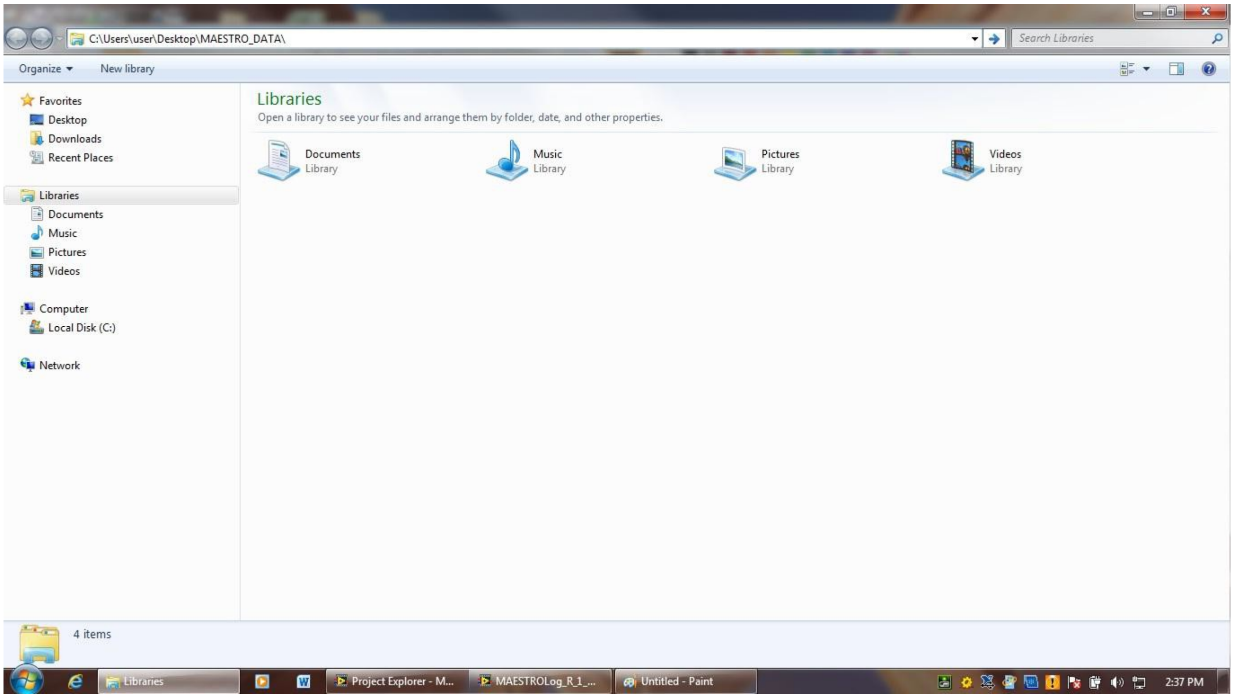
Name	Date modified	Type	Size
25Mar12	3/26/2012 2:30 PM	File	78 KB
24Mar12	3/25/2012 4:14 PM	File	84 KB
23Mar12	3/24/2012 4:14 PM	File	84 KB
14Mar12	3/15/2012 12:19 PM	File	63 KB
13Mar12	3/14/2012 4:14 PM	File	74 KB
22Feb12	2/23/2012 9:21 AM	File	94 KB
21Feb12	2/22/2012 4:14 PM	File	131 KB
20Feb12	2/21/2012 4:14 PM	File	131 KB
19Feb12	2/20/2012 4:14 PM	File	131 KB
18Feb12	2/19/2012 4:14 PM	File	131 KB
17Feb12	2/18/2012 4:14 PM	File	131 KB
16Feb12	2/17/2012 4:14 PM	File	131 KB
15Feb12	2/16/2012 4:14 PM	File	131 KB
14Feb12	2/15/2012 4:14 PM	File	131 KB
13Feb12	2/14/2012 4:14 PM	File	131 KB
12Feb12	2/13/2012 4:14 PM	File	131 KB
11Feb12	2/12/2012 4:14 PM	File	131 KB
10Feb12	2/11/2012 4:14 PM	File	131 KB
09Feb12	2/10/2012 4:14 PM	File	130 KB
08Feb12	2/9/2012 4:14 PM	File	129 KB
07Feb12	2/8/2012 4:14 PM	File	129 KB

We will introduce another method to access the files of your data if you are not sure where the directory folder is located. Locate the path of the directory as designated in the VI (i.e. C:\Users\user\Desktop\MAESTRO_Data). Again, the last part of the path indicates the file name. While the second to last of the path indicates the name of the folder it is currently in. The middle term of the path indicates that folder is on the Desktop. We are only looking for the folder, therefore we will delete the "24Mar12" of the directory. Click on the "start" button and begin to type in "explorer" in the search menu. Then you will select the "windows explorer". The figure below highlights the "windows explorer" and using the start menu and search feature.



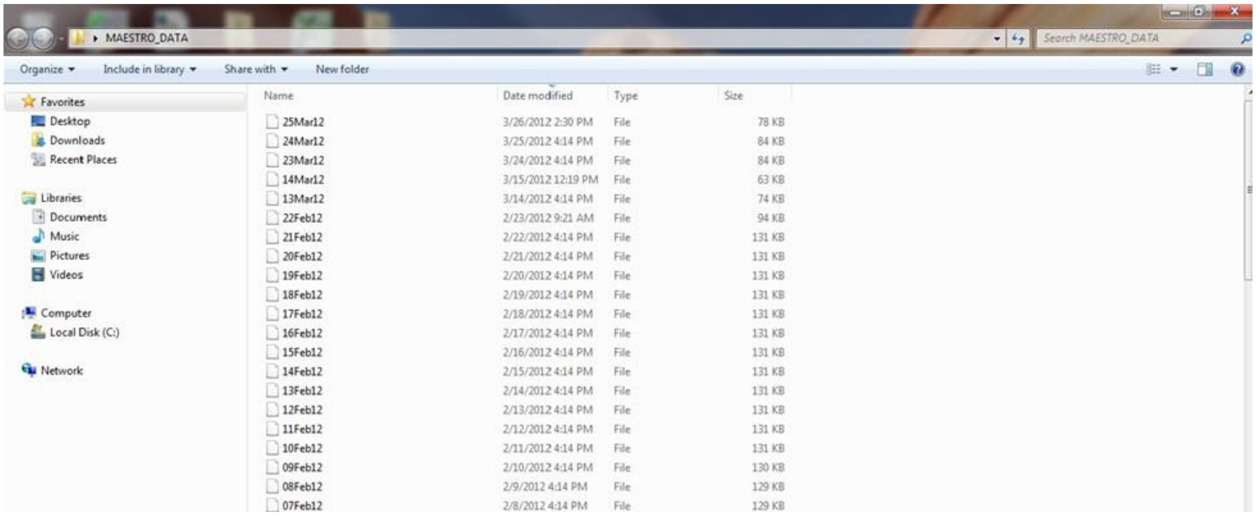
Once "windows explorer" has loaded, enter the directory in the upper box of the window.

(This is equivalent of a URL box such as that you would use in an internet explorer program) Hit the “enter” or return key and you will be directed to the folder with your data. In the figure below, you will notice the modified directory entered in the upper portion of the window.



C:\Users\user\Desktop\MAESTRO_DATA\

The figure displays the redirected window to the folder containing your data.



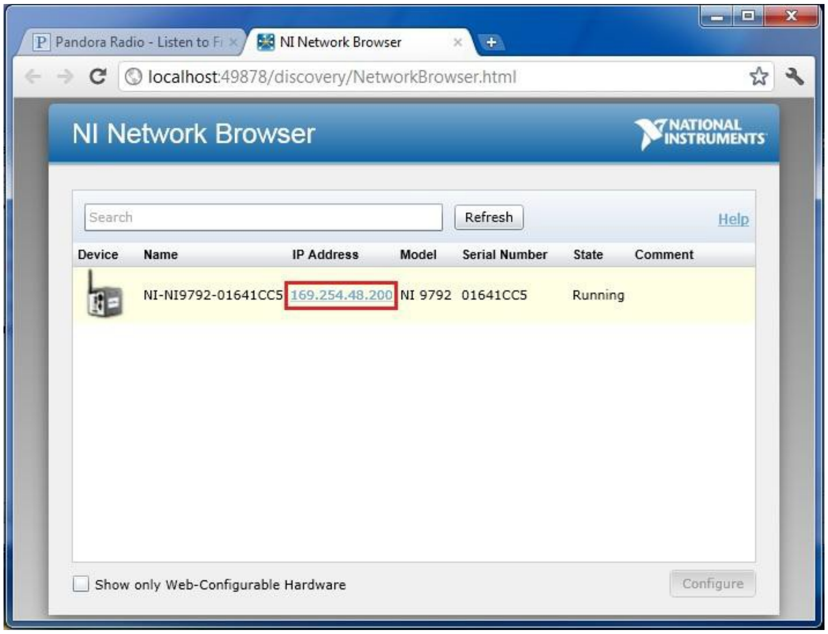
Name	Date modified	Type	Size
25Mar12	3/26/2012 2:30 PM	File	78 KB
24Mar12	3/25/2012 4:14 PM	File	84 KB
23Mar12	3/24/2012 4:14 PM	File	84 KB
14Mar12	3/15/2012 12:19 PM	File	63 KB
13Mar12	3/14/2012 4:14 PM	File	74 KB
22Feb12	2/23/2012 9:21 AM	File	94 KB
21Feb12	2/22/2012 4:14 PM	File	131 KB
20Feb12	2/21/2012 4:14 PM	File	131 KB
19Feb12	2/20/2012 4:14 PM	File	131 KB
18Feb12	2/19/2012 4:14 PM	File	131 KB
17Feb12	2/18/2012 4:14 PM	File	131 KB
16Feb12	2/17/2012 4:14 PM	File	131 KB
15Feb12	2/16/2012 4:14 PM	File	131 KB
14Feb12	2/15/2012 4:14 PM	File	131 KB
13Feb12	2/14/2012 4:14 PM	File	131 KB
12Feb12	2/13/2012 4:14 PM	File	131 KB
11Feb12	2/12/2012 4:14 PM	File	131 KB
10Feb12	2/11/2012 4:14 PM	File	131 KB
09Feb12	2/10/2012 4:14 PM	File	130 KB
08Feb12	2/9/2012 4:14 PM	File	129 KB
07Feb12	2/8/2012 4:14 PM	File	129 KB

Accessing Files After Data Acquisition (NI-9792)

Since the NI-9792 does not need a host, or computer. All the data and project files are saved onto the hard drive enclosed in it. To access and collect these files, an ethernet cable, power supply (such as an electrical outlet), and a computer is required. The first step to collecting the data is to supply power to the NI-9792 gateway and insert the ethernet cable into port #1 (or known as the lower input connection). The figure below displays the correct port on the NI-9792 to insert the Ethernet into. If the Ethernet is plugged into the wrong port, the gateway will not be recognized by the computer. Additionally, flip the “user1” or “no app” switch to the “on” position. These switches turn off the program and failure to do will not able you to access the complete data file.

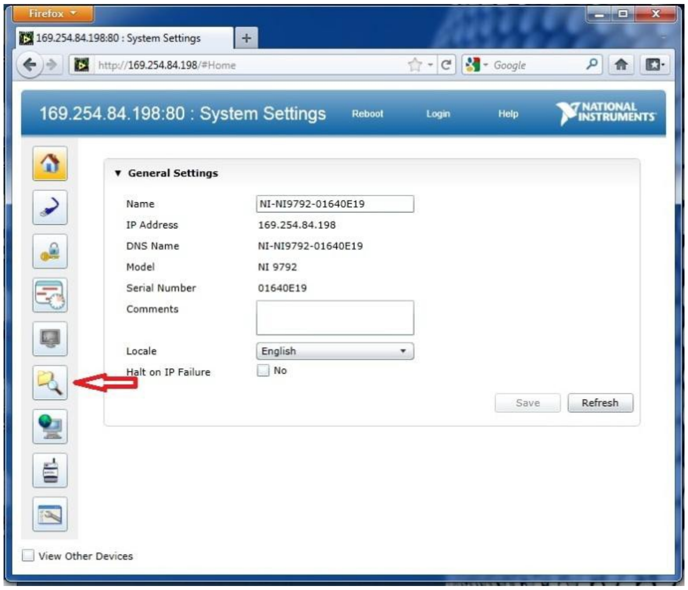
To verify the connection between the computer and gateway, open Measurement & Automation and check there. If there are connection problems, ensure power to gateway, possibly replace Ethernet cable, and check connection ports on both the computer and gateway for contact or debris. Additionally through Measurement & Automation, obtain the IP address on which the gateway is operating on.

To do this, navigate to the top of Measurement & Automation to the “Tools” drop box and select “NI Network Brower”. Once navigated to “NI Network Browser”, the gateway’s IP address along with other credentials will be displayed. Below shows as an example of the “NI Network Browser” and locating the IP address.



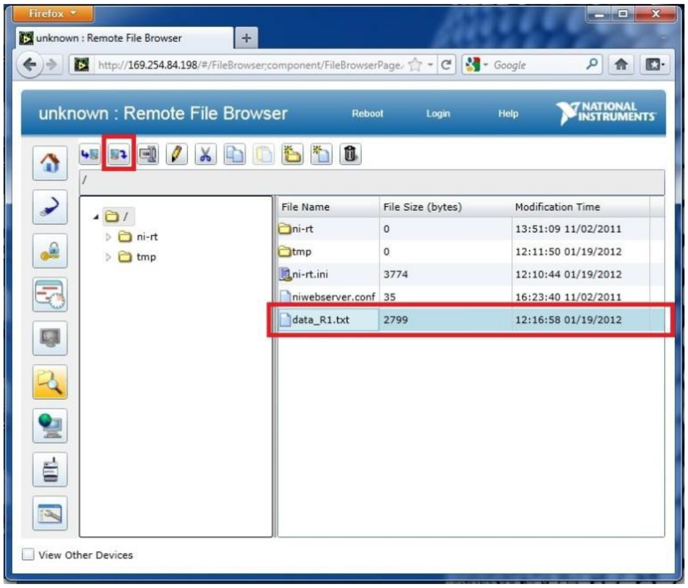
Device	Name	IP Address	Model	Serial Number	State	Comment
	NI-NI9792-01641CC5	169.254.48.200	NI 9792	01641CC5	Running	

Continuing on, open windows explorer or a compatible internet browser and enter the gateway's IP address. (i.e. http://169.254.48.200) You will then be brought to a screen which will look with similar to the figure below and has several options to configure the gateway to your needs. In this application, user(s) will only be using this to access the hard drive of the gateway.



Name: NI-NI9792-01640E19
IP Address: 169.254.84.198
DNS Name: NI-NI9792-01640E19
Model: NI 9792
Serial Number: 01640E19
Comments:
Locale: English
Halt on IP Failure: ☐ No

To access the hard drive, select the sixth option of the left column (folder with magnifying glass). The correct option is designated by the red arrow on the figure above. Once selecting this option, user(s) will have access to the gateway's data and project files. The figure below provides as an example of how a typical gateway is set up. The data file will be in the main directory of the hard drive and opening the main folder will display the data files and project files. To save the data, select the file needed and then select the symbol of the computer with an arrow pointing downwards. The figure below highlights the text file being downloaded and the option to download that file.

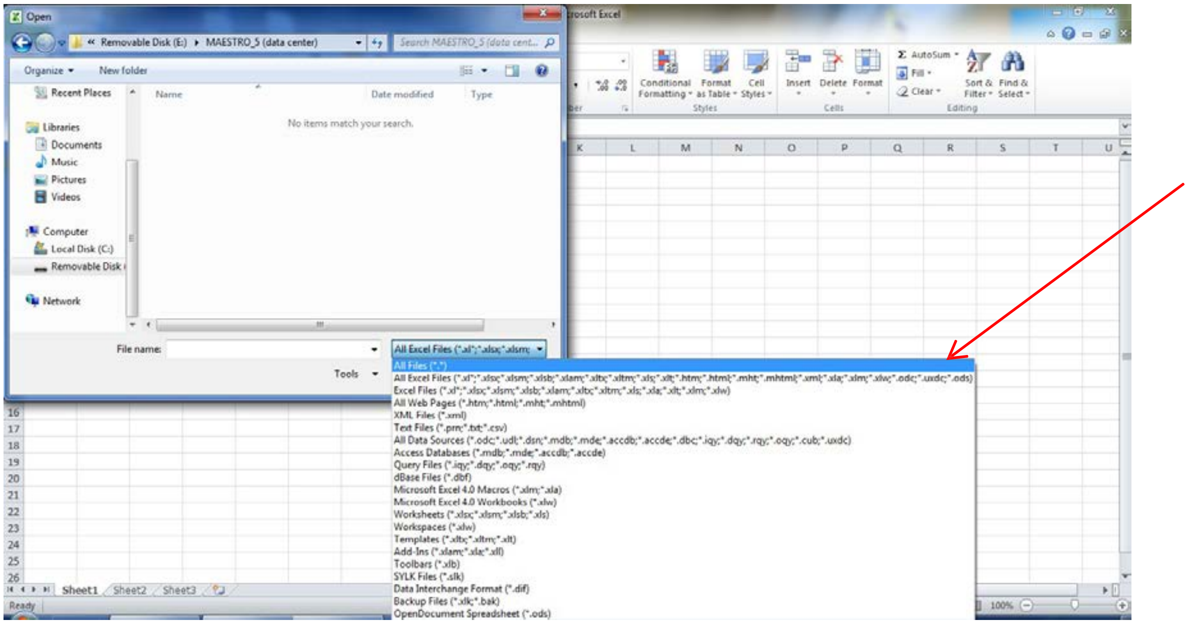


File Name	File Size (bytes)	Modification Time
ni-rt	0	13:51:09 11/02/2011
tmp	0	12:11:50 01/19/2012
ni-rt.ini	3774	12:10:44 01/19/2012
niwebserver.conf	35	16:23:40 11/02/2011
data_R1.txt	2799	12:16:58 01/19/2012

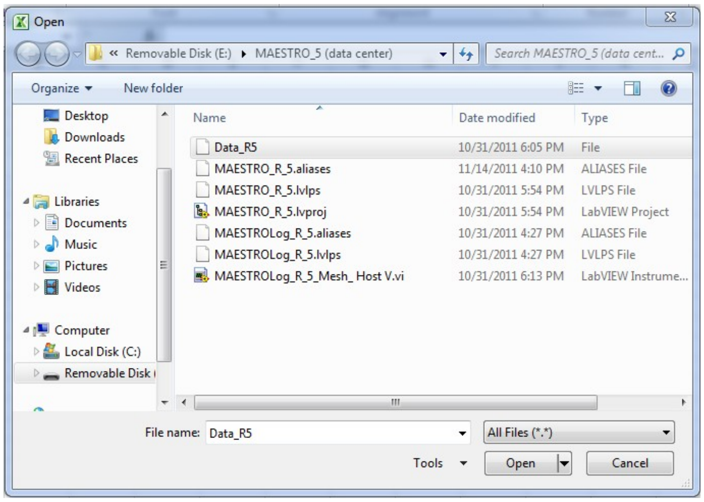
Save the files anywhere of your discretion, but it is most convenient to save them to a folder on the desktop. To open and examine the data file, open excel and complete the necessary steps as directed previously in this manual.

<u>Accessing the Output Data Written to Excel</u>

The existing program writes all collected data into an Excel file. It is easiest to open excel first in order to view these data files. In the file screen, select ‘open’.
Locate the disk containing the collected data.
Excel may display “*No items match your search*”. Click the drop down menu that reads ‘All Excel Files (*.xl; *.xlsx; *.xlm;’ and select ‘All Files (*.*)’



Select the data file (names will vary).

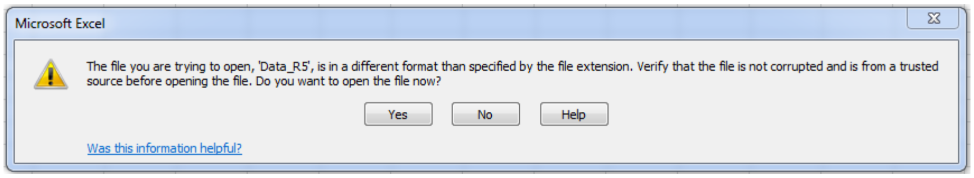


Name	Date modified	Type
Data_R5	10/31/2011 6:05 PM	File
MAESTRO_R_5.aliases	11/14/2011 4:10 PM	ALIASES File
MAESTRO_R_5.lvlps	10/31/2011 5:54 PM	LVLPS File
MAESTRO_R_5.lvproj	10/31/2011 5:54 PM	LabVIEW Project
MAESTROLog_R_5.aliases	10/31/2011 4:27 PM	ALIASES File
MAESTROLog_R_5.lvlps	10/31/2011 4:27 PM	LVLPS File
MAESTROLog_R_5_Mesh_ Host V.vi	10/31/2011 6:13 PM	LabVIEW Instrume...

File name: Data_R5

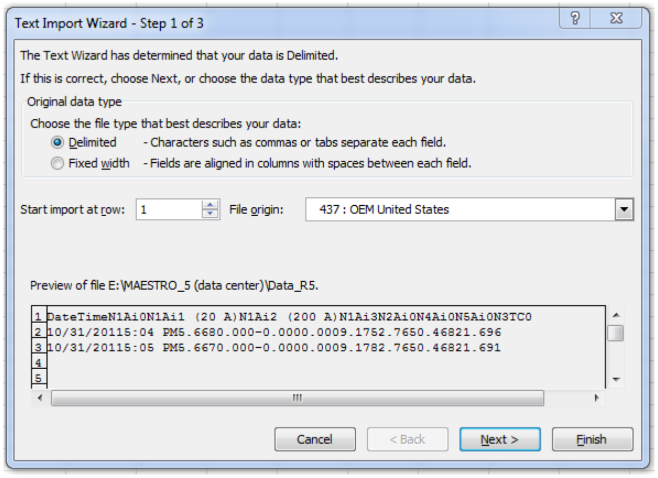
All Files (*.*)

Upon opening you will be prompted with a message. Select ‘yes’.



The file you are trying to open, 'Data_R5', is in a different format than specified by the file extension. Verify that the file is not corrupted and is from a trusted source before opening the file. Do you want to open the file now?

You will be prompted with another message, simply select ‘finish’.



Text Import Wizard - Step 1 of 3

The Text Wizard has determined that your data is Delimited.

If this is correct, choose Next, or choose the data type that best describes your data.

Original data type

Choose the file type that best describes your data:

● Delimited - Characters such as commas or tabs separate each field.

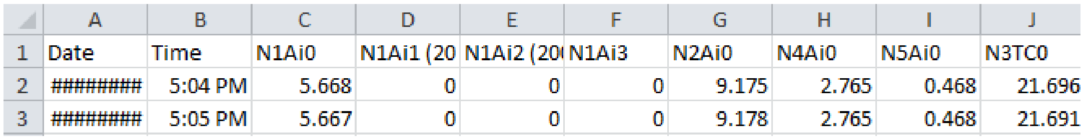
○ Fixed width - Fields are aligned in columns with spaces between each field.

Start import at row: 1 File origin: 437 : OEM United States

Preview of file E:\MAESTRO_5 (data center)\Data_R5.

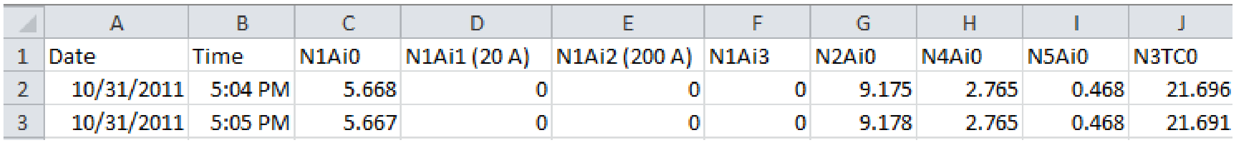
```
1 DateTimeN1Ai0N1Ai1 (20 A)N1Ai2 (200 A)N1Ai3N2Ai0N4Ai0N5Ai0N3TC0
2 10/31/20115:04 PM5.6680.000-0.0000.0009.1752.7650.46821.696
3 10/31/20115:05 PM5.6670.000-0.0000.0009.1782.7650.46821.691
4
5
```

The file will be displayed in a similar manner.



	A	B	C	D	E	F	G	H	I	J
1	Date	Time	N1Ai0	N1Ai1 (20	N1Ai2 (20	N1Ai3	N2Ai0	N4Ai0	N5Ai0	N3TC0
2	########	5:04 PM	5.668	0	0	0	9.175	2.765	0.468	21.696
3	########	5:05 PM	5.667	0	0	0	9.178	2.765	0.468	21.691

Drag the column widths larger to view all the text.



	A	B	C	D	E	F	G	H	I	J
1	Date	Time	N1Ai0	N1Ai1 (20 A)	N1Ai2 (200 A)	N1Ai3	N2Ai0	N4Ai0	N5Ai0	N3TC0
2	10/31/2011	5:04 PM	5.668	0	0	0	9.175	2.765	0.468	21.696
3	10/31/2011	5:05 PM	5.667	0	0	0	9.178	2.765	0.468	21.691

Standard Unit Calibration

Since all of the sensors and equipment output voltages, we will have to convert them to standard units in which they are measured in. For example, the current sensors are measuring the number of amperes at a given time; however the current sensor outputs voltage readings. This portion will involve basic mathematics, but you may refer to a textbook if needed.

The first step is to determine the range of the voltages our sensor is operating at. Observe the current sensor and there will be a label displaying the input and outputs of the sensor. If your sensor does not have a label identifying the input and outputs, consult the manual or manufacturer. For this particular current sensor, the inputs operate at 0-200 amperes in alternating current, and outputs operate at 0-10 volts in direct current. Therefore if we have 200 amperes of current going through the wire, we will have 10 volts of voltage outputting from the sensor. We will take the maximum of each range input and output and divide them

From this, we can induce that input of 20 Amperes is equivalent to output of 1 Volt. (Method #1)

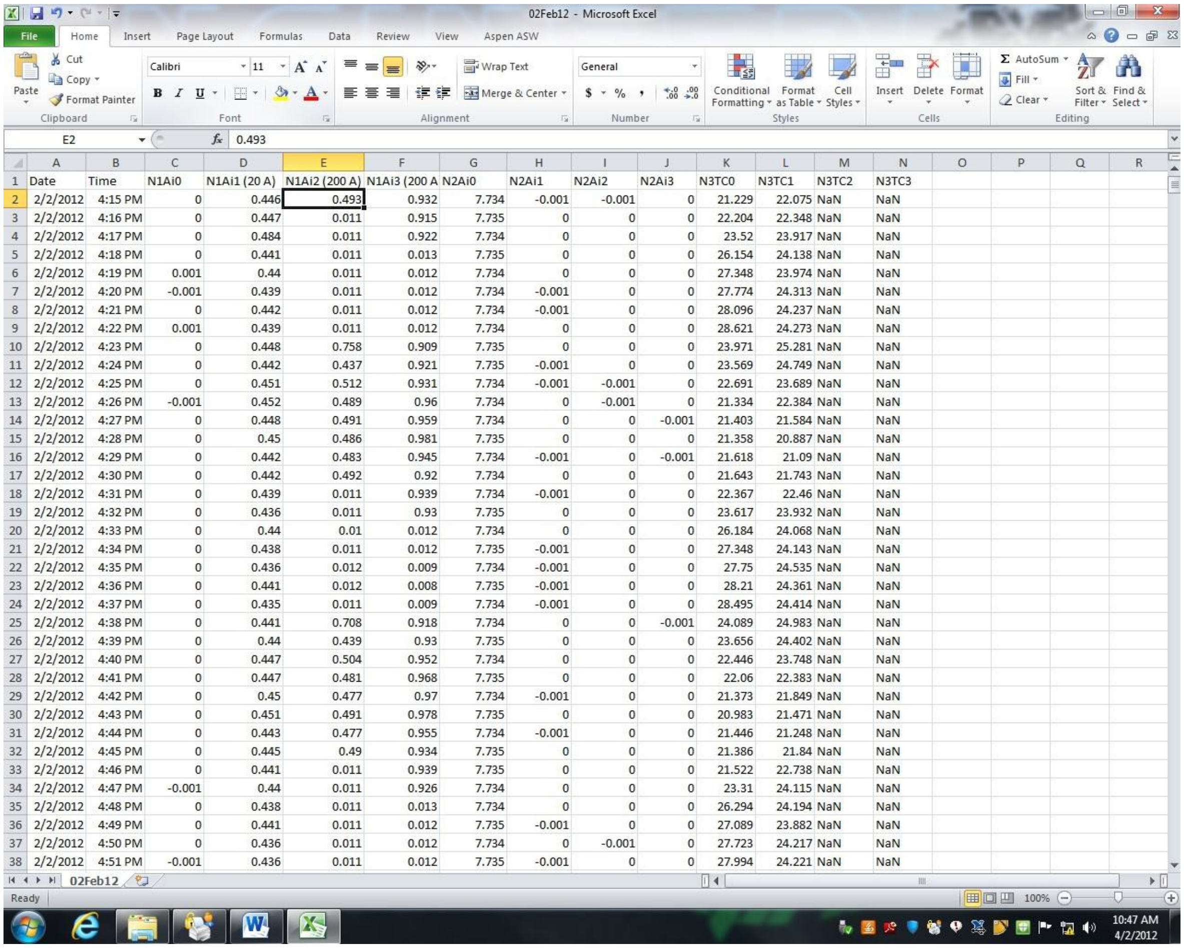
OR

From this, we can induce that output of .05 Volts is equivalent to 1 Ampere. (Method #2)

Either of these methods is correct, which way you use them is entirely your preference. If you notice, the two conversion factors are inversely proportional to each other.

IMPORTANT: It is recommended that you do not make any conversion factors/changes in the block diagram for the output data file showing standard units of the particular measurements. The data should be kept in all terms of voltages and then conversion factors should be made in the data file within excel.

In this section, we will provide an example of the standard unit calibration for a 200 amp AC current transducer sensor. Data has already been collected and the changes will be made via this example. The figure below is a sample of data that has already been previously collected.

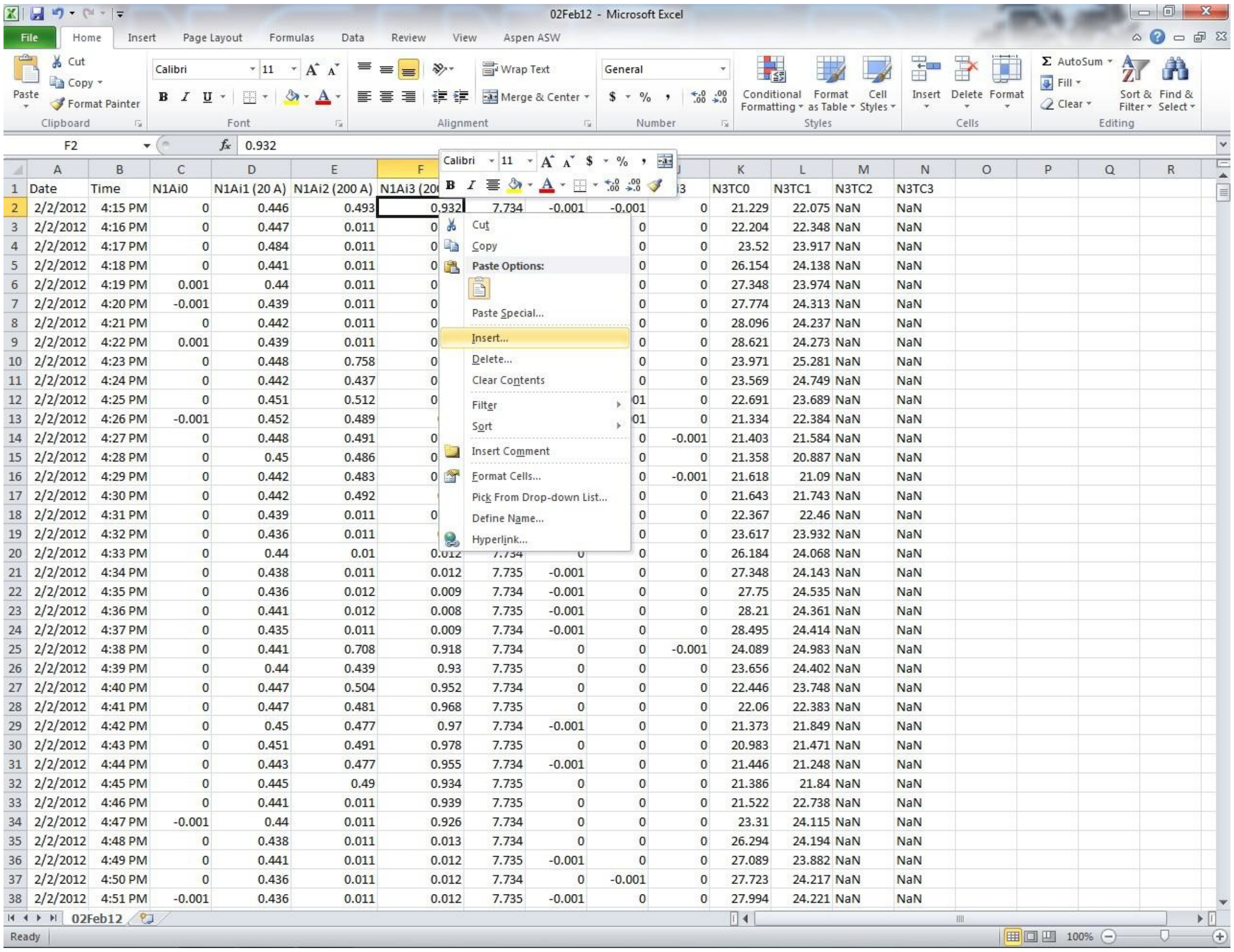


E2 fx 0.493

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Date	Time	N1Ai0	N1Ai1 (20 A)	N1Ai2 (200 A)	N1Ai3 (200 A	N2Ai0	N2Ai1	N2Ai2	N2Ai3	N3TC0	N3TC1	N3TC2	N3TC3
2	2/2/2012	4:15 PM	0	0.446	0.493	0.932	7.734	-0.001	-0.001	0	21.229	22.075	NaN	NaN
3	2/2/2012	4:16 PM	0	0.447	0.011	0.915	7.735	0	0	0	22.204	22.348	NaN	NaN
4	2/2/2012	4:17 PM	0	0.484	0.011	0.922	7.734	0	0	0	23.52	23.917	NaN	NaN
5	2/2/2012	4:18 PM	0	0.441	0.011	0.013	7.735	0	0	0	26.154	24.138	NaN	NaN
6	2/2/2012	4:19 PM	0.001	0.44	0.011	0.012	7.734	0	0	0	27.348	23.974	NaN	NaN
7	2/2/2012	4:20 PM	-0.001	0.439	0.011	0.012	7.734	-0.001	0	0	27.774	24.313	NaN	NaN
8	2/2/2012	4:21 PM	0	0.442	0.011	0.012	7.734	-0.001	0	0	28.096	24.237	NaN	NaN
9	2/2/2012	4:22 PM	0.001	0.439	0.011	0.012	7.734	0	0	0	28.621	24.273	NaN	NaN
10	2/2/2012	4:23 PM	0	0.448	0.758	0.909	7.735	0	0	0	23.971	25.281	NaN	NaN
11	2/2/2012	4:24 PM	0	0.442	0.437	0.921	7.735	-0.001	0	0	23.569	24.749	NaN	NaN
12	2/2/2012	4:25 PM	0	0.451	0.512	0.931	7.734	-0.001	-0.001	0	22.691	23.689	NaN	NaN
13	2/2/2012	4:26 PM	-0.001	0.452	0.489	0.96	7.734	0	-0.001	0	21.334	22.384	NaN	NaN
14	2/2/2012	4:27 PM	0	0.448	0.491	0.959	7.734	0	0	-0.001	21.403	21.584	NaN	NaN
15	2/2/2012	4:28 PM	0	0.45	0.486	0.981	7.735	0	0	0	21.358	20.887	NaN	NaN
16	2/2/2012	4:29 PM	0	0.442	0.483	0.945	7.734	-0.001	0	-0.001	21.618	21.09	NaN	NaN
17	2/2/2012	4:30 PM	0	0.442	0.492	0.92	7.734	0	0	0	21.643	21.743	NaN	NaN
18	2/2/2012	4:31 PM	0	0.439	0.011	0.939	7.734	-0.001	0	0	22.367	22.46	NaN	NaN
19	2/2/2012	4:32 PM	0	0.436	0.011	0.93	7.735	0	0	0	23.617	23.932	NaN	NaN
20	2/2/2012	4:33 PM	0	0.44	0.01	0.012	7.734	0	0	0	26.184	24.068	NaN	NaN
21	2/2/2012	4:34 PM	0	0.438	0.011	0.012	7.735	-0.001	0	0	27.348	24.143	NaN	NaN
22	2/2/2012	4:35 PM	0	0.436	0.012	0.009	7.734	-0.001	0	0	27.75	24.535	NaN	NaN
23	2/2/2012	4:36 PM	0	0.441	0.012	0.008	7.735	-0.001	0	0	28.21	24.361	NaN	NaN
24	2/2/2012	4:37 PM	0	0.435	0.011	0.009	7.734	-0.001	0	0	28.495	24.414	NaN	NaN
25	2/2/2012	4:38 PM	0	0.441	0.708	0.918	7.734	0	0	-0.001	24.089	24.983	NaN	NaN
26	2/2/2012	4:39 PM	0	0.44	0.439	0.93	7.735	0	0	0	23.656	24.402	NaN	NaN
27	2/2/2012	4:40 PM	0	0.447	0.504	0.952	7.734	0	0	0	22.446	23.748	NaN	NaN
28	2/2/2012	4:41 PM	0	0.447	0.481	0.968	7.735	0	0	0	22.06	22.383	NaN	NaN
29	2/2/2012	4:42 PM	0	0.45	0.477	0.97	7.734	-0.001	0	0	21.373	21.849	NaN	NaN
30	2/2/2012	4:43 PM	0	0.451	0.491	0.978	7.735	0	0	0	20.983	21.471	NaN	NaN
31	2/2/2012	4:44 PM	0	0.443	0.477	0.955	7.734	-0.001	0	0	21.446	21.248	NaN	NaN
32	2/2/2012	4:45 PM	0	0.445	0.49	0.934	7.735	0	0	0	21.386	21.84	NaN	NaN
33	2/2/2012	4:46 PM	0	0.441	0.011	0.939	7.735	0	0	0	21.522	22.738	NaN	NaN
34	2/2/2012	4:47 PM	-0.001	0.44	0.011	0.926	7.734	0	0	0	23.31	24.115	NaN	NaN
35	2/2/2012	4:48 PM	0	0.438	0.011	0.013	7.734	0	0	0	26.294	24.194	NaN	NaN
36	2/2/2012	4:49 PM	0	0.441	0.011	0.012	7.735	-0.001	0	0	27.089	23.882	NaN	NaN
37	2/2/2012	4:50 PM	0	0.436	0.011	0.012	7.734	0	-0.001	0	27.723	24.217	NaN	NaN
38	2/2/2012	4:51 PM	-0.001	0.436	0.011	0.012	7.735	-0.001	0	0	27.994	24.221	NaN	NaN

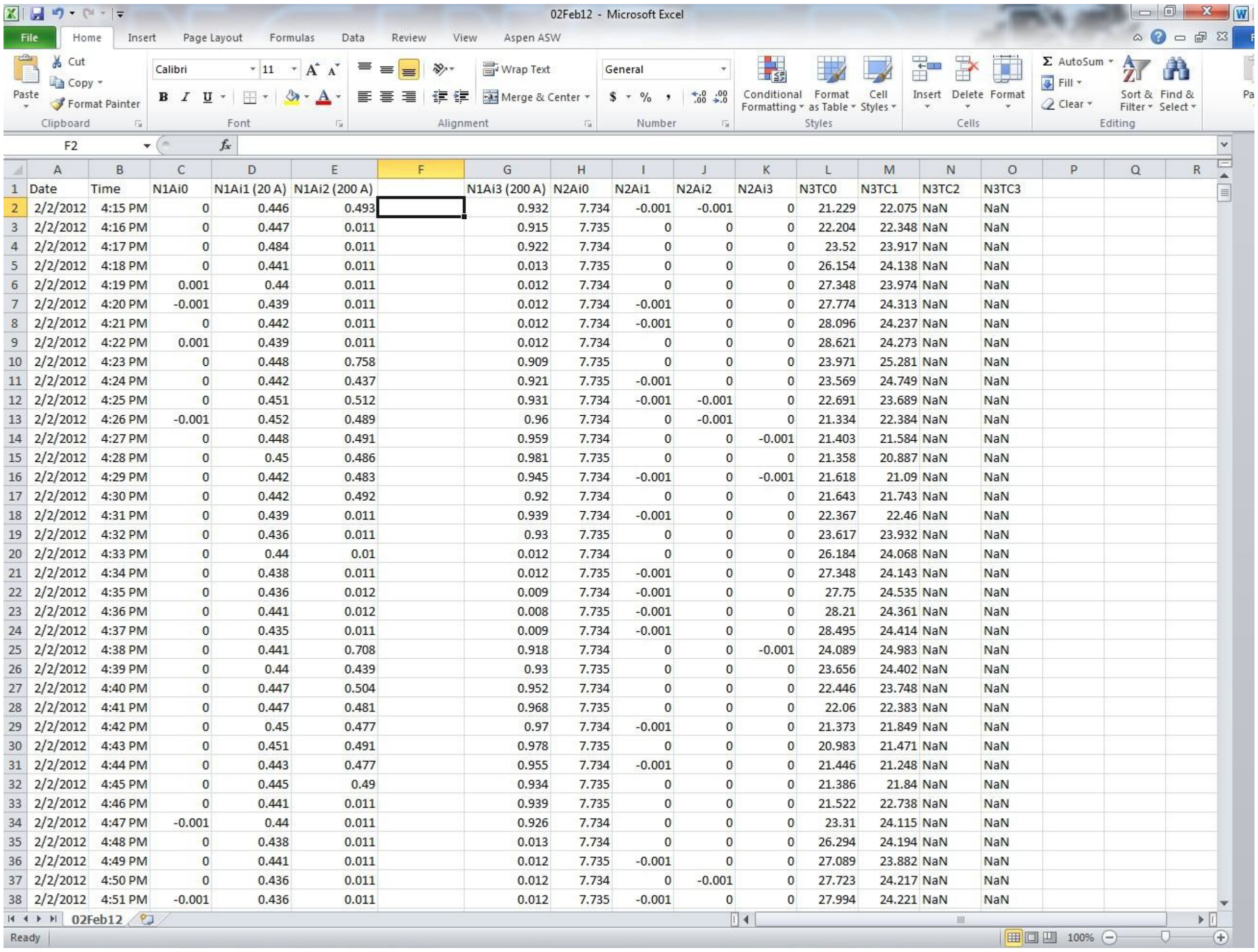
Looking at the column headers, you will see a multitude of measurements being taken such as current, temperature, etc. We will be standardizing the units for the "N1AI2" input (Excel column: 'E'). As shown above, we calculated our conversion factor to be either 20 Amperes per 1 Volt, or .05 Volts per 1 Ampere.

The first step is to create an empty column next to the desired column to be converted into standardized units. To do this, right click on one of the cells to the left or right of your desired columns and select “insert” and then select “entire column”



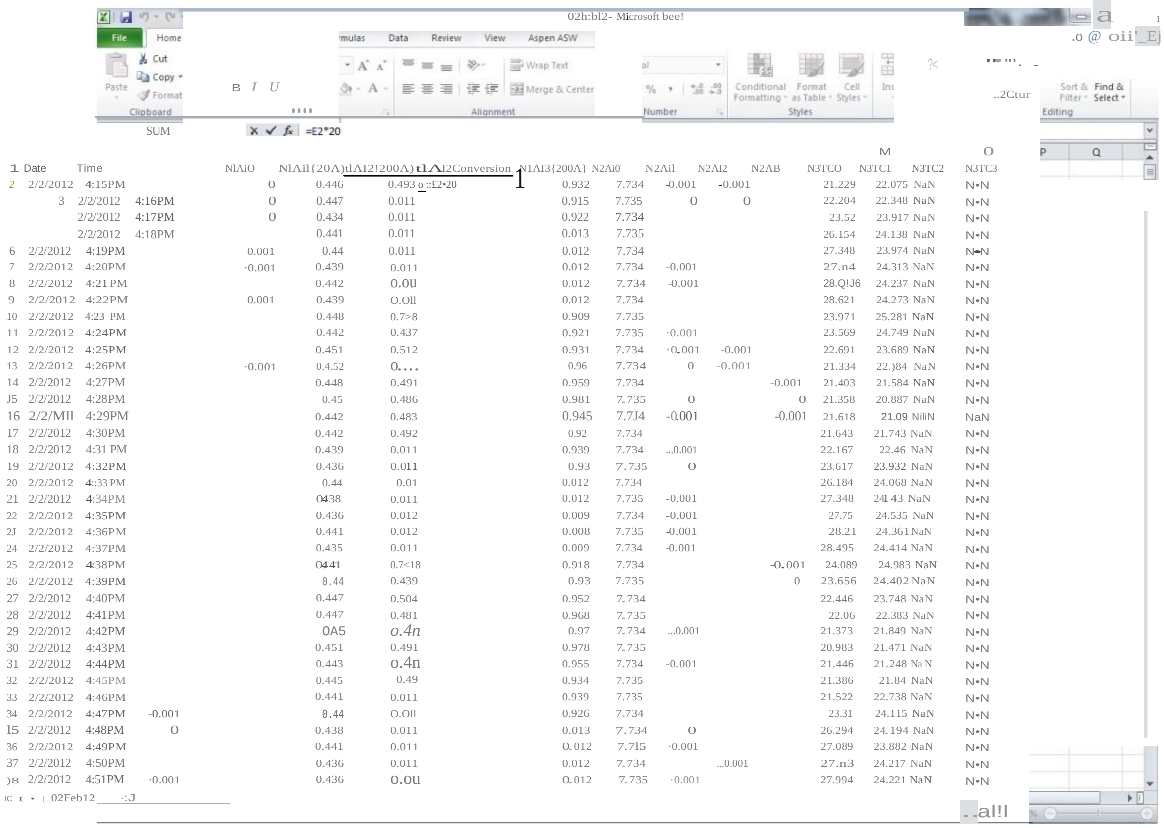
F2 0.932

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Date	Time	N1Ai0	N1Ai1 (20 A)	N1Ai2 (200 A)	N1Ai3 (20				3	N3TC0	N3TC1	N3TC2	N3TC3
2	2/2/2012	4:15 PM	0	0.446	0.493	0.932	7.734	-0.001	-0.001	0	21.229	22.075	NaN	NaN
3	2/2/2012	4:16 PM	0	0.447	0.011	0			0	0	22.204	22.348	NaN	NaN
4	2/2/2012	4:17 PM	0	0.484	0.011	0			0	0	23.52	23.917	NaN	NaN
5	2/2/2012	4:18 PM	0	0.441	0.011	0			0	0	26.154	24.138	NaN	NaN
6	2/2/2012	4:19 PM	0.001	0.44	0.011	0			0	0	27.348	23.974	NaN	NaN
7	2/2/2012	4:20 PM	-0.001	0.439	0.011	0			0	0	27.774	24.313	NaN	NaN
8	2/2/2012	4:21 PM	0	0.442	0.011	0			0	0	28.096	24.237	NaN	NaN
9	2/2/2012	4:22 PM	0.001	0.439	0.011	0			0	0	28.621	24.273	NaN	NaN
10	2/2/2012	4:23 PM	0	0.448	0.758	0			0	0	23.971	25.281	NaN	NaN
11	2/2/2012	4:24 PM	0	0.442	0.437	0			0	0	23.569	24.749	NaN	NaN
12	2/2/2012	4:25 PM	0	0.451	0.512	0			01	0	22.691	23.689	NaN	NaN
13	2/2/2012	4:26 PM	-0.001	0.452	0.489				01	0	21.334	22.384	NaN	NaN
14	2/2/2012	4:27 PM	0	0.448	0.491	0			0	-0.001	21.403	21.584	NaN	NaN
15	2/2/2012	4:28 PM	0	0.45	0.486	0			0	0	21.358	20.887	NaN	NaN
16	2/2/2012	4:29 PM	0	0.442	0.483	0			0	-0.001	21.618	21.09	NaN	NaN
17	2/2/2012	4:30 PM	0	0.442	0.492				0	0	21.643	21.743	NaN	NaN
18	2/2/2012	4:31 PM	0	0.439	0.011	0			0	0	22.367	22.46	NaN	NaN
19	2/2/2012	4:32 PM	0	0.436	0.011				0	0	23.617	23.932	NaN	NaN
20	2/2/2012	4:33 PM	0	0.44	0.01	0.012	7.734	0	0	0	26.184	24.068	NaN	NaN
21	2/2/2012	4:34 PM	0	0.438	0.011	0.012	7.735	-0.001	0	0	27.348	24.143	NaN	NaN
22	2/2/2012	4:35 PM	0	0.436	0.012	0.009	7.734	-0.001	0	0	27.75	24.535	NaN	NaN
23	2/2/2012	4:36 PM	0	0.441	0.012	0.008	7.735	-0.001	0	0	28.21	24.361	NaN	NaN
24	2/2/2012	4:37 PM	0	0.435	0.011	0.009	7.734	-0.001	0	0	28.495	24.414	NaN	NaN
25	2/2/2012	4:38 PM	0	0.441	0.708	0.918	7.734	0	0	-0.001	24.089	24.983	NaN	NaN
26	2/2/2012	4:39 PM	0	0.44	0.439	0.93	7.735	0	0	0	23.656	24.402	NaN	NaN
27	2/2/2012	4:40 PM	0	0.447	0.504	0.952	7.734	0	0	0	22.446	23.748	NaN	NaN
28	2/2/2012	4:41 PM	0	0.447	0.481	0.968	7.735	0	0	0	22.06	22.383	NaN	NaN
29	2/2/2012	4:42 PM	0	0.45	0.477	0.97	7.734	-0.001	0	0	21.373	21.849	NaN	NaN
30	2/2/2012	4:43 PM	0	0.451	0.491	0.978	7.735	0	0	0	20.983	21.471	NaN	NaN
31	2/2/2012	4:44 PM	0	0.443	0.477	0.955	7.734	-0.001	0	0	21.446	21.248	NaN	NaN
32	2/2/2012	4:45 PM	0	0.445	0.49	0.934	7.735	0	0	0	21.386	21.84	NaN	NaN
33	2/2/2012	4:46 PM	0	0.441	0.011	0.939	7.735	0	0	0	21.522	22.738	NaN	NaN
34	2/2/2012	4:47 PM	-0.001	0.44	0.011	0.926	7.734	0	0	0	23.31	24.115	NaN	NaN
35	2/2/2012	4:48 PM	0	0.438	0.011	0.013	7.734	0	0	0	26.294	24.194	NaN	NaN
36	2/2/2012	4:49 PM	0	0.441	0.011	0.012	7.735	-0.001	0	0	27.089	23.882	NaN	NaN
37	2/2/2012	4:50 PM	0	0.436	0.011	0.012	7.734	0	-0.001	0	27.723	24.217	NaN	NaN
38	2/2/2012	4:51 PM	-0.001	0.436	0.011	0.012	7.735	-0.001	0	0	27.994	24.221	NaN	NaN



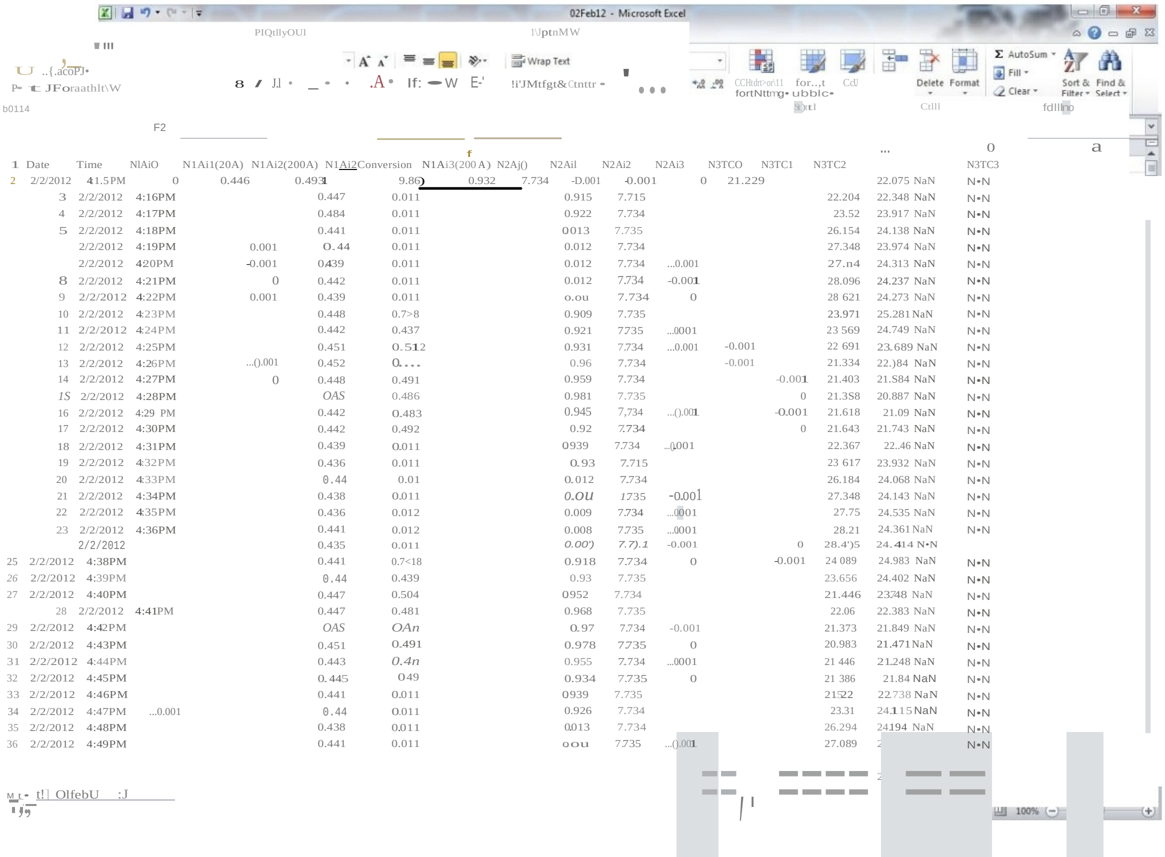
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Date	Time	N1Ai0	N1Ai1 (20 A)	N1Ai2 (200 A)		N1Ai3 (200 A)	N2Ai0	N2Ai1	N2Ai2	N2Ai3	N3TC0	N3TC1	N3TC2	N3TC3			
2	2/2/2012	4:15 PM	0	0.446	0.493		0.932	7.734	-0.001	-0.001	0	21.229	22.075	NaN	NaN			
3	2/2/2012	4:16 PM	0	0.447	0.011		0.915	7.735	0	0	0	22.204	22.348	NaN	NaN			
4	2/2/2012	4:17 PM	0	0.484	0.011		0.922	7.734	0	0	0	23.52	23.917	NaN	NaN			
5	2/2/2012	4:18 PM	0	0.441	0.011		0.013	7.735	0	0	0	26.154	24.138	NaN	NaN			
6	2/2/2012	4:19 PM	0.001	0.44	0.011		0.012	7.734	0	0	0	27.348	23.974	NaN	NaN			
7	2/2/2012	4:20 PM	-0.001	0.439	0.011		0.012	7.734	-0.001	0	0	27.774	24.313	NaN	NaN			
8	2/2/2012	4:21 PM	0	0.442	0.011		0.012	7.734	-0.001	0	0	28.096	24.237	NaN	NaN			
9	2/2/2012	4:22 PM	0.001	0.439	0.011		0.012	7.734	0	0	0	28.621	24.273	NaN	NaN			
10	2/2/2012	4:23 PM	0	0.448	0.758		0.909	7.735	0	0	0	23.971	25.281	NaN	NaN			
11	2/2/2012	4:24 PM	0	0.442	0.437		0.921	7.735	-0.001	0	0	23.569	24.749	NaN	NaN			
12	2/2/2012	4:25 PM	0	0.451	0.512		0.931	7.734	-0.001	-0.001	0	22.691	23.689	NaN	NaN			
13	2/2/2012	4:26 PM	-0.001	0.452	0.489		0.96	7.734	0	-0.001	0	21.334	22.384	NaN	NaN			
14	2/2/2012	4:27 PM	0	0.448	0.491		0.959	7.734	0	0	-0.001	21.403	21.584	NaN	NaN			
15	2/2/2012	4:28 PM	0	0.45	0.486		0.981	7.735	0	0	0	21.358	20.887	NaN	NaN			
16	2/2/2012	4:29 PM	0	0.442	0.483		0.945	7.734	-0.001	0	-0.001	21.618	21.09	NaN	NaN			
17	2/2/2012	4:30 PM	0	0.442	0.492		0.92	7.734	0	0	0	21.643	21.743	NaN	NaN			
18	2/2/2012	4:31 PM	0	0.439	0.011		0.939	7.734	-0.001	0	0	22.367	22.46	NaN	NaN			
19	2/2/2012	4:32 PM	0	0.436	0.011		0.93	7.735	0	0	0	23.617	23.932	NaN	NaN			
20	2/2/2012	4:33 PM	0	0.44	0.01		0.012	7.734	0	0	0	26.184	24.068	NaN	NaN			
21	2/2/2012	4:34 PM	0	0.438	0.011		0.012	7.735	-0.001	0	0	27.348	24.143	NaN	NaN			
22	2/2/2012	4:35 PM	0	0.436	0.012		0.009	7.734	-0.001	0	0	27.75	24.535	NaN	NaN			
23	2/2/2012	4:36 PM	0	0.441	0.012		0.008	7.735	-0.001	0	0	28.21	24.361	NaN	NaN			
24	2/2/2012	4:37 PM	0	0.435	0.011		0.009	7.734	-0.001	0	0	28.495	24.414	NaN	NaN			
25	2/2/2012	4:38 PM	0	0.441	0.708		0.918	7.734	0	0	-0.001	24.089	24.983	NaN	NaN			
26	2/2/2012	4:39 PM	0	0.44	0.439		0.93	7.735	0	0	0	23.656	24.402	NaN	NaN			
27	2/2/2012	4:40 PM	0	0.447	0.504		0.952	7.734	0	0	0	22.446	23.748	NaN	NaN			
28	2/2/2012	4:41 PM	0	0.447	0.481		0.968	7.735	0	0	0	22.06	22.383	NaN	NaN			
29	2/2/2012	4:42 PM	0	0.45	0.477		0.97	7.734	-0.001	0	0	21.373	21.849	NaN	NaN			
30	2/2/2012	4:43 PM	0	0.451	0.491		0.978	7.735	0	0	0	20.983	21.471	NaN	NaN			
31	2/2/2012	4:44 PM	0	0.443	0.477		0.955	7.734	-0.001	0	0	21.446	21.248	NaN	NaN			
32	2/2/2012	4:45 PM	0	0.445	0.49		0.934	7.735	0	0	0	21.386	21.84	NaN	NaN			
33	2/2/2012	4:46 PM	0	0.441	0.011		0.939	7.735	0	0	0	21.522	22.738	NaN	NaN			
34	2/2/2012	4:47 PM	-0.001	0.44	0.011		0.926	7.734	0	0	0	23.31	24.115	NaN	NaN			
35	2/2/2012	4:48 PM	0	0.438	0.011		0.013	7.734	0	0	0	26.294	24.194	NaN	NaN			
36	2/2/2012	4:49 PM	0	0.441	0.011		0.012	7.735	-0.001	0	0	27.089	23.882	NaN	NaN			
37	2/2/2012	4:50 PM	0	0.436	0.011		0.012	7.734	0	-0.001	0	27.723	24.217	NaN	NaN			
38	2/2/2012	4:51 PM	-0.001	0.436	0.011		0.012	7.735	-0.001	0	0	27.994	24.221	NaN	NaN			

Next, we will have to create the formula within excel for the conversion factor. Our new standardized unit values will be going into the new column we just created. Select the second empty cell in our new column and enter your conversion factor and second cell of the column we would like to standard units in. In this example, we will be selecting 'E2' and our conversion formula will be "=E2*20". Hit the enter key, and the new converted value will be displayed in the cell.



SUM =E2*20

	Date	Time	NlAiO	N1Ail{20A)	tlAI2!200A)	tlAI2Conversion	N1AI3{200A}	N2Ai0	N2Ail	N2AI2	N2AB	N3TCO	N3TC1	N3TC2	N3TC3
2	2/2/2012	4:15PM	0	0.446	0.493	o ::£2•20	0.932	7.734	-0.001	-0.001		21.229	22.075	NaN	N•N
3	2/2/2012	4:16PM	0	0.447	0.011		0.915	7.735	0	0		22.204	22.348	NaN	N•N
	2/2/2012	4:17PM	0	0.434	0.011		0.922	7.734				23.52	23.917	NaN	N•N
	2/2/2012	4:18PM		0.441	0.011		0.013	7.735				26.154	24.138	NaN	N•N
6	2/2/2012	4:19PM	0.001	0.44	0.011		0.012	7.734				27.348	23.974	NaN	N•N
7	2/2/2012	4:20PM	·0.001	0.439	0.011		0.012	7.734	-0.001			27.n4	24.313	NaN	N•N
8	2/2/2012	4:21 PM		0.442	0.0u		0.012	7.734	-0.001			28.Q!J6	24.237	NaN	N•N
9	2/2/2012	4:22PM	0.001	0.439	O.Oll		0.012	7.734				28.621	24.273	NaN	N•N
10	2/2/2012	4:23 PM		0.448	0.7>8		0.909	7.735				23.971	25.281	NaN	N•N
11	2/2/2012	4:24PM		0.442	0.437		0.921	7.735	·0.001			23.569	24.749	NaN	N•N
12	2/2/2012	4:25PM		0.451	0.512		0.931	7.734	·0.001	-0.001		22.691	23.689	NaN	N•N
13	2/2/2012	4:26PM	·0.001	0.4.52	0....		0.96	7.734	0	-0.001		21.334	22.)84	NaN	N•N
14	2/2/2012	4:27PM		0.448	0.491		0.959	7.734			-0.001	21.403	21.584	NaN	N•N
J5	2/2/2012	4:28PM		0.45	0.486		0.981	7.735	0		0	21.358	20.887	NaN	N•N
16	2/2/Mll	4:29PM		0.442	0.483		0.945	7.7J4	-0.001		-0.001	21.618	21.09	NiliN	NaN
17	2/2/2012	4:30PM		0.442	0.492		0.92	7.734				21.643	21.743	NaN	N•N
18	2/2/2012	4:31 PM		0.439	0.011		0.939	7.734	...0.001			22.167	22.46	NaN	N•N
19	2/2/2012	4:32PM		0.436	0.011		0.93	7.735	0			23.617	23.932	NaN	N•N
20	2/2/2012	4::33 PM		0.44	0.01		0.012	7.734				26.184	24.068	NaN	N•N
21	2/2/2012	4:34PM		0438	0.011		0.012	7.735	-0.001			27.348	241 43	NaN	N•N
22	2/2/2012	4:35PM		0.436	0.012		0.009	7.734	-0.001			27.75	24.535	NaN	N•N
2J	2/2/2012	4:36PM		0.441	0.012		0.008	7.735	-0.001			28.21	24.361	NaN	N•N
24	2/2/2012	4:37PM		0.435	0.011		0.009	7.734	-0.001			28.495	24.414	NaN	N•N
25	2/2/2012	4:38PM		0441	0.7<18		0.918	7.734			-0.001	24.089	24.983	NaN	N•N
26	2/2/2012	4:39PM		0.44	0.439		0.93	7.735			0	23.656	24.402	NaN	N•N
27	2/2/2012	4:40PM		0.447	0.504		0.952	7.734				22.446	23.748	NaN	N•N
28	2/2/2012	4:41PM		0.447	0.481		0.968	7.735				22.06	22.383	NaN	N•N
29	2/2/2012	4:42PM		0A5	o.4n		0.97	7.734	...0.001			21.373	21.849	NaN	N•N
30	2/2/2012	4:43PM		0.451	0.491		0.978	7.735				20.983	21.471	NaN	N•N
31	2/2/2012	4:44PM		0.443	o.4n		0.955	7.734	-0.001			21.446	21.248	Na N	N•N
32	2/2/2012	4:45PM		0.445	0.49		0.934	7.735				21.386	21.84	NaN	N•N
33	2/2/2012	4:46PM		0.441	0.011		0.939	7.735				21.522	22.738	NaN	N•N
34	2/2/2012	4:47PM	-0.001	0.44	O.Oll		0.926	7.734				23.31	24.115	NaN	N•N
l5	2/2/2012	4:48PM	0	0.438	0.011		0.013	7.734	0			26.294	24.194	NaN	N•N
36	2/2/2012	4:49PM		0.441	0.011		0.012	7.715	·0.001			27.089	23.882	NaN	N•N
37	2/2/2012	4:50PM		0.436	0.011		0.012	7.734		...0.001		27.n3	24.217	NaN	N•N
)8	2/2/2012	4:51PM	·0.001	0.436	0.0u		0.012	7.735	·0.001			27.994	24.221	NaN	N•N



F2

	Date	Time	NlAiO	N1Ai1(20A)	N1Ai2(200A)	N1Ai2Conversion	N1Ai3(200 A)	N2Aj()	N2Ail	N2Ai2	N2Ai3	N3TCO	N3TC1	N3TC2	N3TC3
2	2/2/2012	41.5PM	0	0.446	0.4931	9.86)	0.932	7.734	-D.001	-0.001	0	21.229	22.075	NaN	N•N
3	2/2/2012	4:16PM		0.447	0.011		0.915	7.715				22.204	22.348	NaN	N•N
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	2/2/2012	4:19PM	0.001	O.44	0.011		0.012	7.734				27.348	23.974	NaN	N•N
	2/2/2012	420PM	-0.001	0439	0.011		0.012	7.734	...0.001			27.n4	24.313	NaN	N•N
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9	2/2/2012	4:22PM	0.001	0.439	0.011		o.ou	7.734	0			28 621	24.273	NaN	N•N
10	2/2/2012	4:23PM		0.448	0.7>8		0.909	7.735				23.971	25.281	NaN	N•N
11	2/2/2012	4:24PM		0.442	0.437		0.921	7735	...0001			23 569	24.749	NaN	N•N
12	2/2/2012	4:25PM		0.451	0.512		0.931	7.734	...0.001	-0.001		22 691	23.689	NaN	N•N
13	2/2/2012	4:26PM	...().001	0.452	0....		0.96	7.734		-0.001		21.334	22.)84	NaN	N•N
14	2/2/2012	4:27PM	0	0.448	0.491		0.959	7.734			-0.001	21.403	21.S84	NaN	N•N
1S	2/2/2012	4:28PM		OAS	0.486		0.981	7.735			0	21.3S8	20.887	NaN	N•N
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20	2/2/2012	4:33PM		0.44	0.01		0.012	7.734				26.184	24.068	NaN	N•N
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	2/2/2012			0.435	0.011		0.00')	7.7).1	-0.001		0	28.4')5	24.414	N•N	
25	2/2/2012	4:38PM		0.441	0.7<18		0.918	7.734	0		-0.001	24 089	24.983	NaN	N•N
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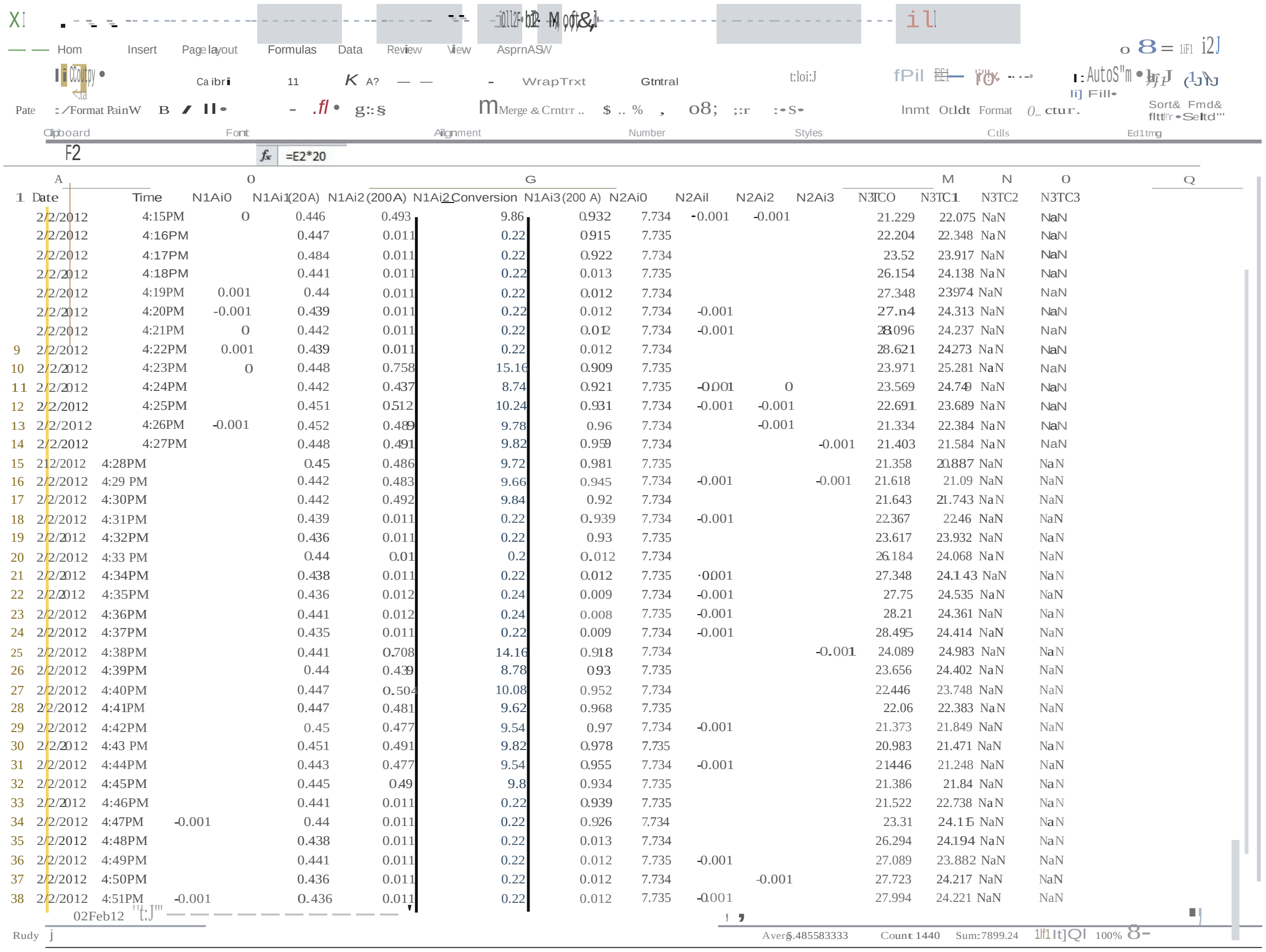
33	2/2/2012	4:46PM		0.441	0.011		0939	7.735				21522	22.738	NaN	N•N
34	2/2/2012	4:47PM	...0.001	0.44	0.011		0.926	7.734				23.31	24.115	NaN	N•N
35	2/2/2012	4:48PM		0.438	0.011		0.013	7.734				26.294	24194	NaN	N•N
36	2/2/2012	4:49PM		0.441	0.011		oou	7.735	...().001			27.089	[illegible]	[illegible]	N•N

37	2/2/2012	4:50PM		0.436	o.ou	0.012	7.734		-0.001	27.723	2	N•N
38	2/2/2012	4:51PM	...().001	0.436	0.011	0.012	7.735	...()	0	27.994		N•N

Then hover your cursor over the lower right hand comer of the newly created cell until a "plus" sign appears. Double-click on the lower right hand comer of the cell, and the column will auto-fill with your conversion factor in respect to our original column's cells.



1	Date	Time	N1Ai0	N1Ai1(20A)	N1Ai2 (200A)	N1Ai2 Conversion	N1Ai3 (200 A)	N2Ai0	N2Ail	N2Ai2	N2Ai3	N3TCO	N3TC1	N3TC2	N3TC3
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	2/2/2012	4:16PM		0.447	0.011	0.22	0.915	7.735				22.204	22.348	NaN	NaN
	2/2/2012	4:17PM		0.484	0.011	0.22	0.922	7.734				23.52	23.917	NaN	NaN
	2/2/2012	4:18PM		0.441	0.011	0.22	0.013	7.735				26.154	24.138	NaN	NaN
	2/2/2012	4:19PM	0.001	0.44	0.011	0.22	0.012	7.734				27.348	23974	NaN	NaN
	2/2/2012	4:20PM	-0.001	0.439	0.011	0.22	0.012	7.734	-0.001			27.n4	24.313	NaN	NaN
	2/2/2012	4:21PM	0	0.442	0.011	0.22	0.012	7.734	-0.001			28.096	24.237	NaN	NaN
9	2/2/2012	4:22PM	0.001	0.439	0.011	0.22	0.012	7.734				28.621	24273	NaN	NaN
10	2/2/2012	4:23PM	0	0.448	0.758	15.16	0.909	7.735				23.971	25.281	NaN	NaN
11	2/2/2012	4:24PM		0.442	0.437	8.74	0.921	7.735	-0.001	0		23.569	24.749	NaN	NaN
12	2/2/2012	4:25PM		0.451	0.512	10.24	0.931	7.734	-0.001	-0.001		22.691	23.689	NaN	NaN
13	2/2/2012	4:26PM	-0.001	0.452	0.489	9.78	0.96	7.734		-0.001		21.334	22.384	NaN	NaN
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17	2/2/2012	4:30PM		0.442	0.492	9.84	0.92	7.734				21.643	21.743	NaN	NaN
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24	2/2/2012	4:37PM		0.435	0.011	0.22	0.009	7.734	-0.001			28.495	24.414	NaN	NaN
25	2/2/2012	4:38PM		0.441	0.708	14.16	0.918	7.734			-0.001	24.089	24.983	NaN	NaN
26	2/2/2012	4:39PM		0.44	0.439	8.78	0.93	7.735				23.656	24.402	NaN	NaN
27	2/2/2012	4:40PM		0.447	0.504	10.08	0.952	7.734				22446	23.748	NaN	NaN
28	2/2/2012	4:41PM		0.447	0.481	9.62	0.968	7.735				22.06	22.383	NaN	NaN
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34	2/2/2012	4:47PM	-0.001	0.44	0.011	0.22	0.926	7.734				23.31	24.115	NaN	NaN
35	2/2/2012	4:48PM		0.438	0.011	0.22	0.013	7.734				26.294	24194	NaN	NaN
36	2/2/2012	4:49PM		0.441	0.011	0.22	0.012	7.735	-0.001			27.089	23.882	NaN	NaN
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38	2/2/2012	4:51PM	-0.001	0.436	0.011	0.22	0.012	7.735	-0.001			27.994	24.221	NaN	NaN

Comprehensive List of Software for Gateway(s)

Software Needed on Host:

IVI Compliance Package 4.3
LabVIEW 2010 SP1
LabVIEW Run-Time 8.2.1
LabVIEW Run-Time 8.5.1
LabVIEW Run-Time 8.6.1
LabVIEW Run-Time 2009 SP1
LabVIEW Run-Time 2009 SP1 (64-bit)
LabVIEW Run-Time 2010 SP1

- Control Design and Simulation Module
- LabVIEW for NI Wireless Sensor Networks
- Sound and Vibration Measurement Suite
- Sound and Vibration Toolkit
- Vision Development Module

LabVIEW SignalExpress 2010
LabWindows/CVI Run-Time 2009
Measurement & Automation Explorer 4.7.7
Measuremens Studio for VS2005

- DotNET
  - Common
  - Vision
  - Vision.Common

Measurement Studio for VS2008

- DotNET
  - Common
  - Common (64-bit)
  - Vision
  - Vision.Common

NI Motion Assistant 2.6
NI PXI Platform Services 2.5.6
NI Script Editor 1.3.2
NI Spy 2.7.2
NI System Configuration 1.1.3
NI Vision Run-Time 2010 SP1

- Image Processing and Machine Vision
- Services

NI-488.2 2.81
NI-DAQmx ADE Support 9.2.3
NI-DAQmx Base 3.4
NI-DAQmx Device Driver 9.2.3
NI-DAQmx MAX Configuration 9.2.3
NI-DCPower 1.4.1

- NI-DCPower Soft Front Panel

NI-DMM 3.0.4
- DMM Soft Front Panel

NI-FGEN 2.7.4
- FGEN Soft Front Panel

NI-HSDIO 1.7.4
NI-HWS 1.4.8
NI-PAL 2.6.3
NI-RFSA 2.3.2
- NI-RFSA Soft Front Panel

NI-RFSG 1.6.4
NI-SCOPE 3.6.2
- SCOPE Soft Front Panel

NI-Serial 3.6
NI-SWITCH 4.1
- Soft Front Panel

NI-TClk 1.8.1
NI-USI 1/0.2
NI VISA 5.0.3
- NiVisaServer.exe
- Nivisaic.exe

NI-VISA Runtime 5.0.3
NI-WSN 1.2
Sound and Vibration Assistant 2010
Vision Builder AI 4.1

<u>Software Needed on NI-9792 Gateway</u>:

NI-WSN 1.2 for LabVIEW 2010 (minimal)
- HTTP Client 1.1
- HTTP Client with SSL Support 1.1
- LabVIEW Real-Time 10.0
- Language Support for LabVIEW RT 1.0.0.3
- NI Scan Engine 2.0
- NI System Configuration Network Support 1.1.2
- NI Web-based Configuration and Monitoring 1.0.0
- NI-Serial RT 3.6.0
- NI-VISA 5.0
    - NI-VISA Server 5.0
- NI-WSN 1.2
- Remote Panel Server for LabVIEW RT 3.0.0
- Run-Time Engine for Web Services 3.0.0
- SSL Support for LabVIEW RT 3.0.0
- Variable Client Support for LabVIEW RT 1.7.0

WSN Host API 1.2.0

Appendix C

MAESTRO Developed Case Studies

GET PLUGGED INTO...

MAESTRO

Missouri Agricultural Energy Saving Team - A Revolutionary Opportunity

Sunrise Farms Case Study

BACKGROUND

Farming in the Hentges family is part of their genetic makeup. Wayne Hentges is the third generation working on the family farm. He's been farming since he was old enough to help out and hasn't looked back. In 1998, Wayne's parents purchased Sunrise Farms in Tipton, Missouri, and gave Wayne some of the land to farm for himself. Soon after he received an additional 16 acres from his family for a broiler barn, and eventually Wayne purchased a second broiler farm on his own. In 2001, Wayne was also able to purchase land on which his farm residence is located. Farming agrees with Wayne!

Today, Sunrise Farms operates four poultry houses where 5.5 flocks are raised every year with approximately 23,800 birds per flock per house. Annually, a total of 523,600 birds are raised at this location. The target growth weight for the birds is seven pounds when they are shipped to Tyson, the farm's integrator. Wayne's farm purchased 128,960 kilowatt-hours (kWh) of electricity last year. At $0.08 per kWh, that adds up to $10,689 – not a small sum. When Wayne heard of the opportunity to save money by installing energy efficient equipment, he immediately applied to receive funding through the MAESTRO.

FARM ENERGY MANAGEMENT PLAN

The energy management plans use an analysis of the farmer's utility bills, data gathered on site, and engineering calculations to determine the breakdown of the farm's current energy use. The report offered recommendations for energy efficiency and included a description of each recommendation, energy savings associated with the technologies, cost savings, and payback in years.

UNIVERSITY OF MISSOURI Extension EnSave

> *"The whole process has been great. I've saved lots of money, and my flocks have gotten a lot better; even the bird quality is better. This has been more than just energy savings. The audit was able to let me know what things I could put in and change in my barns to help save money and energy."*
>
> — WAYNE HENTGES, POULTRY FARMER

MAESTRO

Missouri Agricultural and Energy Savings Team — A Revolutionary Opportunity

The MAESTRO Program is funded by the U.S. Department of Energy through the American Recovery and Reinvestment Act, and administered by the Missouri Department of Agriculture, the University of Missouri and EnSave, Inc. The program is the first agriculture program funded by the U.S. Department of Energy's Better Buildings program.

The program provided energy management plans, technical assistance reports, and home energy audits to non-CAFO livestock producers in Missouri. Eligible farmers could receive incentives up to 75% of the total project cost to implement energy efficient equipment on their operations. To date, over 120 farmers in Missouri have received more than $800,000 in funding to implement energy efficient equipment on their farms.

Contact EnSave at (800) 732-1399 to learn more about the MAESTRO program and energy efficiency opportunities for the farm.

Sunrise Farms Savings

» **Wayne Hentges could save $11,498 per year by implementing energy efficient equipment mentioned here.**

Measure	Electricity Savings (in kWh)	Energy Savings (in MBtu)	Installed Cost	Energy Annual Cost Savings	Estimated Payback (in Years)
Poultry Lighting	34,518	118	$8,280	$2,862	2.9
Other Lighting	2,219	8	$740	$184	4.0
Air Heating and Building Environment	(3,714)	593	$45,765	$8,452	5.4
TOTALS	**33,023**	**719**	**$54,785**	**$11,498**	**4.8**

ANNUAL SAVINGS FOR SUNRISE FARMS

The energy management plan is a tool to help the farmer prioritize investments in energy efficiency. The plan not only included recommendations for equipment that Wayne could implement, but it also cautioned against making other energy efficiency investments due to low energy savings and long payback periods. For example, the energy management plan determined that it would not be cost-effective for Sunrise Farms to insulate tunnel intake doors or add an inch of polyurethane foam to one of the house ceilings. The excessive payback period for each offers beneficial information to the farmer to help make sound business decisions.

	Current Status	With All Recommendations Implemented	Savings (Total)
Electricity Used in 12-month Period (kWh)	128,960	95,937	33,023
Annual Cost of Energy @ $0.08/kWh	$10,689	$7,675	$2,738
Propane Used in 12-month Period (gal)	53,839	47,254	6,585
Annual Cost of Propane @ $1.33/gallon	$71,628	$62,848	$8,760
		TOTAL ANNUAL SAVINGS	**$11,498**

UNIVERSITY OF MISSOURI Extension EnSave

Energy Efficient Changes for Sunrise Farms

LED Lighting

Metal Halide Fixtures

Insulation

To learn more about the MAESTRO program, contact a MAESTRO representative at **(800) 732-1399**, or visit **moagenergysavings.com**.

BEST PRACTICE: REPLACE POULTRY HOUSE LIGHTING

Sunrise Farms is using 184 100 watt incandescent lights and 24 150 watt high pressure sodium (HPS) bulbs for brooding purposes in all the houses. These lights collectively consume 33% of the electricity used on the farm. Per Wayne Hentges' request, the report analyzed LED bulbs and recommended replacing the 100 watt incandescent lights with 12 watt LEDs. The report also offered alternative lighting recommendations in the energy audit report to provide the farmer with other options for energy efficient lighting.

BEST PRACTICE: REPLACE SECURITY LIGHTS (GENERAL LIGHTING)

Wayne has the opportunity to improve the energy efficiency of his outdoor lighting. If Wayne replaced the four 250 watt mercury vapor fixture yard lights with 150 watt pulse start metal halide fixtures he could save 2,219 kWh or $184 per year.

Lighting can be one of the most attractive energy efficiency upgrades because it tends to have a short payback period and is simple to replace. This is certainly the case for Sunrise Farms. If Wayne were to implement the poultry house lighting and the security lighting recommendations above, he would save 36,737 kWh with an average payback period of 3.4 years. By installing just the lighting recommendations in the energy audit report, Wayne would save a total of $3,046 per year!

BEST PRACTICE: AIR HEATING AND BUILDING ENVIRONMENT RECOMMENDATIONS

Houses 1-4 currently have an R-10.6 insulation value in the walls. Savings calculations for adding insulation to the walls assume increasing the R-value of the wall insulation by R-7. The report recommends adding a minimum of R-7 insulation value to the walls of houses 1-4.

The energy management plan also recommends:

- Insulating the knee walls in all houses with one inch polyurethane HD foam
- Insulating the brood curtains in all houses
- Adding six stir fans per house
- Adding one inch polyurethane foam to the sidewalls in all the houses
- Adding one inch polyurethane foam in the end walls of all the houses

Retrofitting un-insulated or poorly insulated poultry houses offers both energy savings and productivity benefits. Studies at Alabama's Auburn University have been conducted on poultry houses to quantify the energy savings and the productivity benefits. These studies have identified energy savings of up to 35%. Insulating side walls allows the grower greater control over the environment inside the house. Unwanted air leaks can be eliminated and provide better heating and cooling of the birds.

UNIVERSITY OF MISSOURI Extension EnSave

Murray Volk Case Study

BACKGROUND

Murray Volk got his start in the dairy business as a high school student in New York, when a local farmer needing a farm hand showed him how to milk his first cow. Murray spent six years learning the ropes of dairy farming, and eventually the same farmer who taught him to milk lent him the money to start his own dairy. That was fifty years ago, and in 1977 Murray left behind the snow of the Northeast and opened a dairy in Missouri where he has farmed ever since. Today, Murray and his son Aaron milk 120 cows in Graff, Missouri.

The Volks produce 1.7 million pounds of milk per year, and use about 40,000 kilowatt-hours of electricity per year. At a cost of $0.08 per kilowatt hour, the farm spends about $3,200 a year for that electricity. The Volks are aware of the need to make their farm as efficient as possible. They had previously invested in energy efficiency, so when they learned of an opportunity uncover additional energy savings, they jumped at the chance.

FARM ENERGY MANAGEMENT PLAN

The energy management plans use an analysis of the farmer's utility bills, data gathered on site, and engineering calculations to determine the breakdown of the farm's current energy use. The report offered recommendations for energy efficiency and included a description of each recommendation, energy savings associated with the technologies, cost savings, and payback in years.

UNIVERSITY OF MISSOURI Extension EnSave

> *"The process is very simple and very easy. The audit provided me a lot more information than I was looking for, which wasn't a bad thing!"*
>
> – MURRAY VOLK, DAIRY FARMER

MAESTRO

Missouri Agricultural and Energy Savings Team — A Revolutionary Opportunity

The MAESTRO Program is funded by the U.S. Department of Energy through the American Recovery and Reinvestment Act, and administered by the Missouri Department of Agriculture, the University of Missouri and EnSave, Inc. The program is the first agriculture program funded by the U.S. Department of Energy's Better Buildings program.

The program provided energy management plans, technical assistance reports, and home energy audits to non-CAFO livestock producers in Missouri. Eligible farmers could receive incentives up to 75% of the total project cost to implement energy efficient equipment on their operations. To date, over 120 farmers in Missouri have received more than $800,000 in funding to implement energy efficient equipment on their farms.

Contact EnSave at (800) 732-1399 to learn more about the MAESTRO program and energy efficiency opportunities for the farm.

Volk Farm Savings

» Murray and Aaron Volk could see 58% energy savings by making the recommended measures in their farm energy management plan.

Measure	Electricity Savings (in kWh)	Energy Savings (in MBtu)	Installed Cost	Energy Annual Cost Savings	Estimated Payback (in Years)
Lighting	1,962	7	$126	$158	.08
Hot Water (compressor heat recovery unit)	6,902	24	$3,949	$555	7.1
Milk Harvest (variable speed drive)	8,961	31	$5,700	$720	7.9
Milk Cooling (plate cooler)	5,281	18	$3,700	$425	8.7
TOTALS	**23,106**	**80**	**$13,475**	**$1,858**	**7.3**

ANNUAL SAVINGS FOR THE VOLK FARM

Murray and Aaron could save $1,858 per year by implementing the energy efficient equipment mentioned above. Murray was particularly interested in a plate cooler for his operation because he was concerned the milk was not cooling fast enough. A plate cooler would save about $425 in electricity costs per year while also helping cool the milk faster.

The energy management plan is a tool to help the farmer prioritize investments in energy efficiency. Therefore, the report not only included recommendations for equipment the Volks could implement, but it also cautioned against making other energy efficiency investments due to low energy savings and long payback periods. For example, the report determined that a milk transfer pump variable speed drive, new compressors, and a new vacuum pump motor would not be cost-effective for the Volks due a payback period that exceeded the life of the equipment. This information is critical to farms who are looking for guidance about where to invest their energy efficiency dollars and make informed business decisions.

	Current Status	With All Recommendations Implemented	Savings (Total)
Energy Used in 12-month Period (kWh)	40,095	16,989	23,106
Annual Cost of Energy @ $0.08/kWh	$3,208	$1,359	$1,849

Energy Efficient Changes for the Volk Farm


Compact Fluorescent Lighting


Compressor Heat Recovery System


Variable Speed Drive


Plate Cooler

BEST PRACTICE: REPLACE INEFFICIENT LIGHTING

The Volk farm had several incandescent lights in the milk parlor, milk room, and shop. The report recommended replacing these lights with compact fluorescent lighting, and in some cases would recommend installation of T-8 or T-5 electronically ballasted strip fluorescent fixtures. On many farms, lighting can be one of the most attractive energy efficiency upgrades because it tends to have a short payback period and is simple to replace. That is certainly the case on the Volk farm, with the energy savings from the recommended lighting paying for the investment cost in just 9 1/2 months.

BEST PRACTICE: COMPRESSOR HEAT RECOVERY SYSTEM

A compressor heat recovery system captures waste heat from cooling milk and uses it to pre-heat water. This reduces the energy used by the farm's water heater. The Volks currently heat about115 gallons of water each day from 56 degrees Fahrenheit to 150 degrees Fahrenheit. The compressor heat recovery system will save about $500 per year in energy costs, and larger farms that heat more water can expect additional savings.

BEST PRACTICE: MILK VACUUM PUMP VARIABLE SPEED DRIVE

The Volks can benefit from installing a variable speed drive for their milk vacuum pump, which adjusts the speed of the pump motor to provide only the amount of vacuum needed. The current pump motor always runs at the highest speed, using more energy than necessary. The installation of a variable speed drive for the milk vacuum pump will save the Volks about
$720 per year.

BEST PRACTICE: PLATE COOLER

A plate cooler, also called a pre-cooler, uses cold water to chill the warm milk before it enters the bulk tank. This reduces the run time of the compressors needed to cool the milk, saving energy. A plate cooler also cools the milk faster, which was a concern for the Volks.

To learn more about the MAESTRO program, contact a MAESTRO representative at **(800) 732-1399**, or visit **moagenergysavings.com**.

Appendix D

Considerations of Structure for Future Programs for Farm Energy Efficiency

The following lessons learned/recommendations are taken from best practices the team implemented and discovered in the course of the MAESTRO program.

- Size and type of animal husbandry vary greatly across agricultural enterprises and geographic locations, so flexibility should be built into any program of a national scope to allow states to create tools and practice mixes to best serve their unique situations.
- Technical standards must be clear and consistent throughout the program period.
- A simple application process is needed, and all requirements such as historic preservation reviews and minimum efficiency improvement levels should be clearly stated in all information provided during the recruitment period.
- Much energy efficiency can be captured in farming operations, but often significant improvements can be captured by not using a whole-building concept as is used in homes and apartment buildings. Lighting improvement is a particularly pertinent example of this situation. A Technical Assistance report (instead of a full-site energy audit) can be a solution to help farmers interested in only one or two systems on the farm
- Irrigation systems and grain handling systems are examples of agricultural processes that lend themselves to analysis from an industrial process perspective more so than a building efficiency perspective. Programs that are meant to help address whole-farm efficiency improvement should allow for a mix of building and process type assessment and upgrade procedures.
- Cost-share or rebate payments are good tools to help farmers overcome their hesitancy to adopt new systems or practices that will save them energy.
- Decisions to move to energy efficient equipment should be made from a business management perspective rather than, as in home efficiency improvements, as a matter of improved comfort.
- Programs focused on small farms should leverage additional resources to help farmers pay for farm energy audits and upgrades. An example is leveraging financial assistance through the USDA Natural Resources Conservation Service to help farmers afford their comprehensive farm energy audits.
- State energy offices (SEOs) could develop synergistic agreements with University Extension to provide support to Extension that would allow them to use their resources to provide energy audits to the farm community and thus overcome the barrier of “too expensive” audits.
- Extension can provide on-line assessment tools for farmers to use for many practices. Provision of such tools can serve as means to increase awareness of the potential dollar savings and work process improvements that can be made through energy efficiency upgrades. This could then lead to wider acceptance of the benefits of such ~~a~~udits by the broader agricultural sector.
- Farm energy efficiency programs should have flexibility to focus on farm-specific measures.
- Where possible, farm energy incentives should focus on grants rather than loans since farmers already have access to loans and are reluctant to take on more debt.
- Requiring a partial payment for services up front gives farmers more ownership in the process since they have money at stake.
- Having program policies and procedures complete prior to program launch allows program to be up and running without working through logistics. This alleviates miscommunications and helps with consistent messaging.

Appendix E

Midwest Energy Efficiency Research Program (MEERC)

Background:

Energy is vital to the economy of states, the nation and the well being of our citizens. Energy is necessary to make our buildings comfortable, to light our world, to transport people and products and produce and process the necessities of life. It is the foundation of our way of life and our economy. Regardless of the source of energy, fossil, nuclear or renewables, using our energy wisely is economically and environmentally sound. Just implementing the technology that is "on the shelf" today could save forty percent of the energy consumed today not to mention the future potential savings that will be accomplished through scientific research underway.

In order to enhance the economic and wise use of energy, the University of Missouri (MU), a leading resource in energy efficiency (EE) in the Midwest, brought together it's campus-wide sustainable energy programs that are focused on all aspects of the economy into an interdisciplinary cohesive and synergistic consortium – MEERC. Why focus on the Midwest? Each geographical region of the United States has unique opportunities to take advantage of energy efficiency technology.

During the formation process of MEERC, numerous state and university EE programs were evaluated, assessed and analyzed. After this assessment and analysis, the successful UC Davis EE Center (with components of other regional programs) laid the foundation for MEERC. MEERC was most closely modeled after the successful UC Davis energy efficiency center because of its track record of integrating partners and its EE research and outreach programs.

MEERC became a part of the University of Missouri because it is a comprehensive Midwest, Land Grant University, and member of the Association of American Universities (AAU). This affiliation enabled MEERC to engage key professional expertise such as law, medicine, agriculture, engineering, business, as well as its powerful and effective outreach capacity through its Extension system. Perhaps the key to partnering with the University of Missouri is simply "energy efficiency cannot and will not be accomplished solely in an academic environment, it will happen with strong connections to the private business and industry sectors. The University is 1 of 15 universities in the country recently awarded the "The Innovation and Prosperity Award" by the National Association of Public and Land Grant Universities because of its ability to "put technology to work".

MEERC's Vision:

Be the strategic, solutions-oriented energy efficiency organization that will develop energy efficiency technology and at the same time educate citizens, businesses and industries about the economic and environmental benefits of energy efficiency.

MEERC's Goals:

MEERC has three goals:

- Advance EE in the Midwest by increasing knowledge and understanding of EE in business, industry, agriculture and the public.
- Assist EE business development.
- Partner with industry to develop and advance EE technologies.

MEERC's Operation:

The Director operates MEERC on a day-to-day basis. As an affiliated University of Missouri entity, the Director incorporates the appropriate dimensions of a premier Land Grant University, and member of the Association of American Universities (AAU) to focus on energy efficiency programs. An Internal Advisory Board consisting of individuals within the university with energy efficiency expertise guides the Director. An External Advisory Board consisting of members from the public and private sector who have knowledge and the capacity to advance the energy efficiency business provide critical and key direction to the MEERC Director. The Internal Board's mission is to assure the technical and educational energy efficiency programs have clear and defined goals in alignment with the External Advisory Board recommendations. The External Advisory Board's function is to assure that MEERC is focused on critical and achievable objectives that are presented to the board from the director.

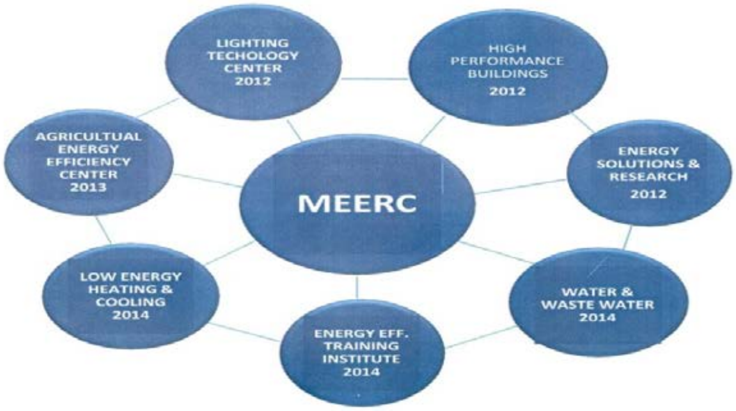
MEERC's Capacity:

The MEERC consortium enables the separate university EE programs at the University of Missouri to work together by forming "Centers" that focus key strengths of the existing work. MEERC and its centers capitalize on the unique and comprehensive capacity of the university with its research, outreach and education capacity. MEERC organized around six Centers that focus on Midwest EE uniqueness:

- *High Performance Buildings Center,* (Midwest is one of six US regions defined by DOE)
- *Agricultural EE Center,*(Midwest is the major agricultural production region of the US)
- *Lighting Research Center* (Midwest lighting demands are a composite of the US demands)
- *Low Energy Heating and Cooling Center*,(Midwest has great potential for ground source energy recovery)
- *Energy Solutions and Research Center* (Midwest unique R&D opportunities need to be explored)
- *Water and Wastewater Center* (Midwest has unique water capacity and agricultural, industrial and individual consumption.)

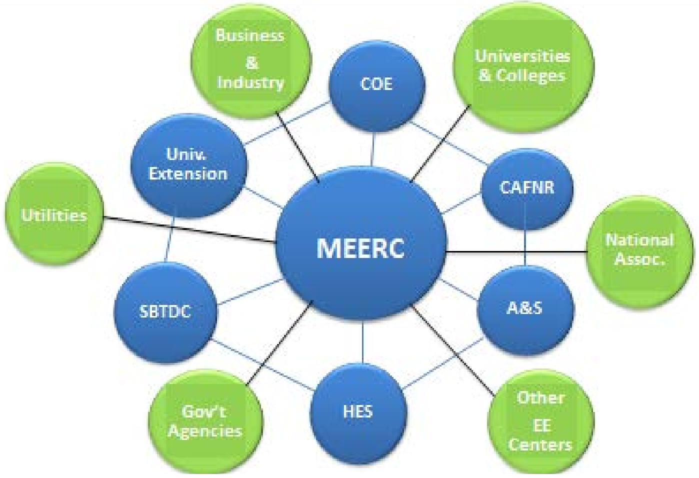
MEERC recently added to the Consortium unit the *Energy Efficiency Training Institute* that is modeled after the existing and successful University of Missouri Extension's Fire Training Institute and Emergency Preparedness Institute. These existing institutes reach to large and small communities throughout the state.

The comprehensive and unique technology collaboration is graphically represented with a timeline of initiation into the MEERC is presented below.



MEERC's Participants:

MEERC is fully cognizant that energy efficiency is not achieved in an isolated academic environment. To effectively implement energy efficiency a partnership must be developed with other universities, technical colleges, national associations, EE centers, government agencies, utilities, and the business and industry sectors of our economy. MEERC has established these connections as graphically demonstrated below.



MEERC's Funding:

The University of Missouri through its MIZZOU Advantage initiative, electrical coops and private sector entities recognized the critical importance of an integrated and effective energy efficiency program and provided the funds to initiate the development of MEERC.

MEERC"s long range financial plan is a self-sufficiency business model with limited base support from the university. The 5-year goal for each center is to enhance their technical and educational objectives through financial independence. This goal will be accomplished through integrated funding from foundations, private sector contributions and affiliate company memberships, research, and research and development contracts and grants, and EE coursework & training program fees.

MEERC Successes:

MEERC has been in operation for only a year but has achieved significant progress. Some highlights are listed below:

- Development of an Evaluation, Monitoring and Verification (EM&V) system to investigate the energy efficiency of agriculture facilities in the state of Missouri
- Launched an effort to foster the adoption of energy saving technology by Missouri Livestock Producers
- Participated in the design, construction and monitoring (post-construction) of a high performance energy efficient house called "Active Houses".
- Geothermal heating & cooling in a commercial poultry production research system
- Participating in a demonstration of a deep energy retrofit project optimization for a PACE financed commercial project in a 1930s commercial building in St. Louis
- Development of a national energy efficiency training institute (EETI)

- Graduate Certificate in Energy Efficiency (EE)
- Planning the EEBA/NAHB 2014 National Conference to be held in St. Louis
- Survey of water & wastewater systems in Missouri regarding EE technology applications
- Medical facilities energy audit protocol is presently under development.

MEERC's Future:

MEERC's future is bright because it provides the multidisciplinary environment that attracts and connects key academic expertise with knowledgeable private sector professionals to join together in a consortium that will solve energy efficiency challenges. Additionally, because MEERC is a consortium and not a rigid or structured organization, it is flexible to adjust to take advantage of new and exciting opportunities. As with all innovative and visionary organizations, initial funding as well as long term funding is of essence. MEERC has successfully obtained funds during its first year of operation and has plans underway to expand program development.

Appendix F

University of Missouri Extension Guide Sheets

Top Money Saving Practices on Dairy Farms in Missouri

Energy Series Information: *This publication is one in a series of Farm Energy Conservation guides that discusses energy savings on the farm. Data in this series were obtained through the Missouri Agricultural and Energy Savings Team – A Revolutionary Opportunity (MAESTRO) Program. The MAESTRO program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. Specifically, participants in the program were livestock producers who were not required to be permitted as confined animal feeding operations (CAFO). MAESTRO was a grant-funded program that provided cost-share assistance to implement energy efficient practices recommended in energy management plans though low-interest loans and rebates. Although these guides refer to energy savings in Missouri, many of the concepts described may apply to operations throughout the Midwest. If you are interested in more energy savings recommendations, please visit http://extension.missouri.edu/energy.*

The dairy industry continues to be an important component of Missouri's economy. According to University of Missouri's Dairy Resource Guide, as of December, 2012, Missouri had 1,348 permitted dairy operations. Of these operations, 950 were Grade A dairies while the remaining 398 were manufacturing dairies. And according to USDA's Milk Production Report of 23 Selected States, Missouri's milk production in July 2013 averaged 109 million pounds. Dairy operations use a substantial amount of energy as equipment is needed to move and cool milk. However, substantial energy and monetary savings can be realized by implementing energy efficient measures that are recommended in an energy audit.

An energy audit is an in-depth examination of a farm that determines: If/how energy is being lost, which systems are operating inefficiently, and what type of cost-efficient measures can be put into place to make the farm more energy efficient. To explain further, an energy audit evaluates a farm's current operation, makes calculations of existing systems' efficiency, and compares it to proposed new systems. Based on these calculations, an Agricultural Energy Management Plan (AgEMP) is created to explain what energy savings measures are recommended for the farm. AgEMP reports may qualify for financial assistance from various funding sources, which includes but are not limited to federal grants, loan programs, and/or energy tax credits.

Energy audits and AgEMPs were created for Missouri dairy producers through the MAESTRO Program. As stated earlier, this program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. All data that will be shared on energy saving potential on dairy farms were obtained through this program. It is important to note that participants of this program were not required to be permitted as a Confined Animal Feeding Operation (CAFO) and therefore will represent farms smaller in size than their CAFO counterparts. When entering the MAESTRO program, information was gathered on producers' current energy usage. On average, dairy farmers enrolled in the program used an average of 63,543 kwh and 893 gallons of propane.

Farmers who implemented energy efficient retrofits that saved electricity saved an average of 25 percent, while those who implemented energy efficient retrofits that saved propane saved an average of 40 percent. These savings reflect the costs of implementing energy efficient retrofits that were recommended in EMPs as well as Technical Assistance (TA) reports. The chart below indicates current usage or amount of energy used when entering the program, as well as average energy savings per year.

Average Energy Savings Per Farm

Energy Type	Current Usage	Average Savings/ Farm	Average Percent Savings Per Farm	Dollar Savings Per Year	Installed Cost Per Practice
Electricity	63,543 kwh	16,125 kwh	25 percent	$481.80	$4,958.88
Propane	893 gallons	360 gallons	40 percent	$883.29	4,287.56

The energy savings shown from practices recommended through the MAESTRO program were determined by analyzing energy usage data and current equipment used in individual dairy farms in Missouri. As part of the MAESTRO program, audits were conducted and AgEMPs were generated for farmers in Missouri. Participants were able to apply for grant funding to help cost-share implementation of these new practices. In the MAESTRO program, researchers found that dairy operations had four practices that saved the most energy. Those practices include Lighting, Compressor Heat Recovery (CHR) Unit, Milk Harvest, and Milk Cooling.

Lighting

Switching from older incandescent lighting to CFL or linear fluorescent lighting can make a substantial difference in terms of energy used on the farm, depending on the number of light fixtures. According to the MAESTRO Best Practices Guide developed by EnSave, CFLs deliver the same amount of light as incandescent bulbs, but only use ¼ the energy. Although the cost of CFLs bulbs is higher up front, it is important to remember that they last up to 25 times longer than incandescent, which will help save money in the long run. In terms of linear fluorescent bulbs, new T8 and T5 bulbs are replacing older T-12s as they use 20 percent less energy and generate less noise, have more light per watt, better color rendering, minimal flickering and cooler operation.

Upgrading to energy efficient lighting is a relatively easy change to make in an operation due to the fact farmers can often install themselves. The majority of the lighting retrofits changed inefficient fixtures to CFL bulbs and/or linear fluorescents through the MAESTRO Program. In addition, there were retrofits from inefficient fixtures to new Pulse Start Metal Halide (PSMH) bulbs, and in one instance LED lighting. Below are average lighting practice energy savings per farm that were reflected in the MAESTRO program.

Lighting Practices Energy Average Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
1,541 kwh	$307.79	$178.52

Water Heating (CHR)

Compressor Heat Recovery (CHR) units can be one of the most cost-effective purchases a dairy farmer can make, according to MAESTRO Best Practices Guide. How does it work? When milk cools in a bulk tank or with a chiller, compressors are used to remove the heat from the milk. A CHR re-uses this heat to heat water, and can raise water temperatures as high as 110 degrees Fahrenheit.

Up to 50 percent of the energy required for water heater can be recovered from heat that is removed from milk. If farmers need to purchase for a water heater, it is important to note that the efficiency of water heaters vary greatly. An electric water heater converts electricity into water at nearly 100 percent, while gas and oil water heaters have a thermal efficiency of 80 percent unless they are of the condensing type that has a thermal efficiency in the 95 percent range. This is the percent of energy that is transferred to the water.

Water heaters differ widely in the standby losses. You should consult with dealers on ratings of various water heaters. Below are average CHR practice energy savings per farm for the MAESTRO program, and they are broken down for electric and propane hot water heaters.

Electric Hot Water Heater Average Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
10,076 kwh	$874.50	$5,269.50

Propane Hot Water Average Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
530 gallons	$1,008.25	$4,267.25

Milk Cooling

Milk cooling usually consumes the largest percentage of energy use on dairy farms. By switching from an inefficient, older reciprocation compressor to a newer scroll compressor, a farmer can save up to 41 percent energy, according to the MAESTRO Best Practices Guide. There are fewer moving parts and scroll compressors are not that much higher in terms of up-front pricing. It is important to note when purchasing a new bulk tank, you should specify that the compressors be a scroll type. This type of compressor works well in cool weather and can start under any system load.

Plate cooler can be a significant addition to a farm when considering energy savings. Milk typically comes from the cow at 98 degrees Fahrenheit and if a dairy operation does not have a milk pre-cooler, flows into a receiver and is then pumped into the bulk tank. Compressors then cool the milk to a storage temperature of about 38 degrees Fahrenheit. A plate cooler is a set of stainless steel plates that are installed in the milk line before the bulk tank. Well water passes through the plate cooler in one direction and absorbs heat from the warm milk pumped through the plate cooler in the opposite direction. According to the MAESTRO Best Practices Guide, by using a pre-cooler, a dairy farm that produces three million pounds of milk per year can save about $800 annually. Below is table outlining information regarding energy savings for milk cooling retrofits in the MAESTRO program. These savings include switching from reciprocating to scroll compressors and/or the addition of a plate cooler.

Milk Cooling Retrofits Average Energy Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
5,535 kwh	$468.67	$4,976.75

Milk Harvest: VSD Controller

Before Variable Speed Drive (VSD) controllers were available, dairy producers had to run their pumps at a constant high speed to perform adequately during the short intervals of high vacuum need, according to the MAESTRO Best Management Practices. Now, VSD controllers regulate the speed of the milk vacuum pump motor.

How does it work? VSD measures how much vacuum the system requires and regulates the speed of the pump motor. The result is that the pump and motor only work as hard as they need to, which leads to substantial savings. How much savings will occur depend on the horsepower of the pump and the number of milkings. In addition to energy savings, additional benefits of VSD include a quieter working environment and the fact it maintains a constant vacuum level. It is important to note that through the MAESTRO program, faculty found that many times a new motor will also need to be installed in conjunction with VSD as older motors with low horsepower are not adequate for the new VSD digital controllers.

Milk Harvest Retrofits Average Energy Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
6,720 kwh	$583.21	$6,854.38

How to Determine Need for Energy Audit

Dairy producers considering an energy audit may wonder how they can determine if an audit is really needed for their particular operation. There are four basic questions they can ask themselves. If they can answer yes to any of the questions below, an energy audit may be in order.

1. Has equipment recently been added to the farm?
2. Are there new industry developments or technology that's more efficient?
3. Has farming operation grown or expanded to include new property?
4. Is there an opportunity to apply for financial assistance (grant, loan or cost-share)?

For more information, visit http://extension.missouri.edu/energy. This site provides access to tools developed by MU Extension that will allow producers to conduct self evaluations to assess potential energy loss/inefficiency on their specific type of farming operation.

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Notes

Original work created by Montana State University Extension and the University of Wyoming.

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Top Energy Saving Practices on Poultry Farms

Energy Series Information: *This publication is one in a series of Farm Energy Conservation guides that discusses energy savings on the farm. Data in this series were obtained through the Missouri Agricultural and Energy Savings Team – A Revolutionary Opportunity (MAESTRO) Program. The MAESTRO program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. Specifically, participants in the program were livestock producers who were not required to be permitted as confined animal feeding operations (CAFO). MAESTRO was a grant-funded program that provided cost-share assistance to implement energy efficient practices recommended in energy management plans though low-interest loans and rebates. Although these guides refer to energy savings in Missouri, many of the concepts described may apply to operations throughout the Midwest. If you are interested in more energy savings recommendations, please visit http://extension.missouri.edu/energy.*

The poultry industry continues to be an important component of Missouri's economy, with the 2007 census reporting $1,676,632,000 in sales. This figure represents 16.8 percent of Missouri's agricultural sales and ranks third in Missouri sales only behind grain crops and cattle. Poultry operations are highly efficient and raise birds in an environment where temperature, humidity, and lighting are closely monitored to raise high-quality birds. Due to the fact birds are raised in such a closely-monitored environment, poultry operations are also large consumers of propane and electricity. However, substantial energy and monetary savings can be realized by implementing energy efficient measures that are recommended in an energy audit.

An energy audit is an in-depth examination of a farm that determines: If/how energy is being lost, which systems are operating inefficiently, and what type of cost-efficient measures can be put into place to make the farm more energy efficient. To explain further, an energy audit evaluates a farm's current operation, makes calculations of existing systems' efficiency, and compares it to proposed new systems. Based on these calculations, an Agricultural Energy Management Plan (AgEMP) is created to explain what energy savings measures are recommended for the farm. AgEMP reports may qualify for financial assistance from various funding sources, which includes but are not limited to federal grants, loan programs, and/or energy tax credits.

Energy audits and AgEMPs were created for Missouri poultry producers through the MAESTRO Program. As stated earlier, this program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. All data that will be shared on energy saving potential on poultry farms were obtained through this program. It is important to note that participants of this program were not required to be permitted as a Confined Animal Feeding Operation (CAFO) and therefore will represent farms smaller in size than their CAFO counterparts. When entering the MAESTRO program, information was gathered on producers' current energy usage. Poultry producers used an average of 77,645 kilowatt hours (kwh) of electricity and 20,816 gallons of propane per year before converting to energy efficient equipment. The average size poultry farm participating in the program varied regarding the type of birds raised, i.e. broilers, turkeys, pullets, or layers. Broiler farms averaged 83,533 birds per farm and raised six flocks per year. Turkey farms averaged 23,829 birds per farm and raised four flocks per year. Pullet farms averaged 81,000 per farm and raised two flocks per year. Layer farms averaged 48,000 birds per farm and raised one flock per year. The chart below indicates current usage or amount of energy used when entering the program, average energy and monetary savings per year, as well as the installed cost of implementing energy efficient retrofits that were recommended in EMPs as well as Technical Assistance (TA) reports.

Average Energy Savings Per Farm

Energy Type	Current Usage	Average Savings Per Farm	Average Percent Savings Energy Per Farm	Dollar Savings Per Year	Installed Cost Per Practice
Electricity	77,645 kwh	25,349 kwh	33 %	$1,783.81	$13,347.11
Propane	20,816 gallons	2,325 gallons	11 %	$3,550.53	$17,529.90

The energy savings shown from practices recommended through the MAESTRO program were determined by analyzing energy usage data and current equipment used in individual poultry farms in Missouri. As part of the MAESTRO program, audits were conducted and AgEMPs were generated for farmers in Missouri. Participants were able to apply for grant funding to help cost-share implementation of these new practices. In the MAESTRO program, researchers found that poultry operations had three practices that saved the most energy. Those practices include: LED lighting, conversion from pancake to brooder radiant heaters, and insulation. It is important to note that all growers who had a contract with poultry companies discussed all changes/upgrades with their respective contractors before proceeding with retrofits.

Lighting

Lighting choices are significantly important to poultry producers as they directly affect bird performance and profits. In recent years, the trend towards tunnel-ventilated poultry houses for broilers has increased the need for quality uniform lighting. As reported in the MAESTRO Best Practices Guide developed by EnSave, LEDs are 85 percent more efficient than incandescent bulbs. An added benefit is that LEDs maintain high-quality lighting for years after installation. In fact, University of Arkansas Research and Extension data indicate LEDs are maintaining 70 to 80 percent of their light output two years after being installed in broiler houses. To ensure farmers are seeing this high light output for years after installation, the MAESTRO Best Practices Guide offers these four tips: 1) Choose lights specifically designed for your type of livestock. 2) Choose lights that come with a 3-year warranty or better. 3) Choose lights that have a color temperature between 3,500 and 6,400 Kelvin. 4) Check with your integrator to make sure LEDs are permitted.

Upgrading to energy efficient lighting is a relatively easy change to make in an operation due to the fact farmers can often install themselves. The change from incandescent to LEDs was recommended frequently in the MAESTRO program as the majority of the MAESTRO participants who owned poultry operations used 60-watt incandescent bulbs to light their poultry houses. Sixty three percent of all poultry producers who installed energy efficient measures as part of the MAESTRO program installed LED lighting in their poultry houses. By installing this energy efficient technology, they were able to save $1,903.04 per year on electric expenses.

Average Lighting Practice Energy Savings Per Farm

Energy Savings	Dollar Savings Per Farm	Installed Cost
22,455 kwh	$1,903.04	$10,618.94

LEDs are being used in broiler, turkey, layer, and breed production facilities on a more frequent basis as the cost per bulb continues to decline. Cost-share assistance offered through the MAESTRO program also offered assistance with the cost of the LED bulbs for poultry producers who installed this type of lighting. It is important to recognize the life-cycle cost rather than the up-front cost when deciding whether or not to install this type of lighting due to its low energy cost and relatively long life cycle. Initial costs will be offset by long-term energy savings and life of bulbs.

Radiant Brooder Heaters

Radiant heaters are preferred over conventional hot air furnaces due to the fact they are more energy efficient and can travel through still air and heat the birds on the floor. Radiant brooders have 15 to 30 percent lower fuel consumption than hot air heaters and pancake brooders. However, radiant brooders also have the distinct advantage of being a heating system that will heat the birds and the floor rather than the air. According to MAESTRO Best Practices Guide, these distinct advantages make radiant heaters an optimum choice when selecting energy efficient heating for poultry houses. In addition, radiant heaters can also be mounted higher in the house, eliminating the need to raise and lower the heaters. They also take less time to pre-heat a house. Radiant heating also offers options to producers as they can choose to install a conventional radiant brooder or a radiant tube heater, in which hot air from a burner is forced through a metal pipe causing the pipe to heat up to temperatures as high as 1000 degrees F. The outer surface of the pipe then radiates the heat to solid objects, such as the floor. Heat reflected upward is deflected downward by reflectors.

Thirty seven percent of all poultry producers who installed energy efficient measures as part of the MAESTRO program installed one form of radiant heating in their poultry houses. By installing this energy efficient technology, they saved $3,669.23 per year on propane expenses.

Average Radiant Brooder Heater Savings Per Farm

Propane Savings	Dollar Savings Per Year	Installed Cost
28,864 gallons	$3,669.23	$16,873.40

Radiant brooders have a larger radiant zone vs. a pancake heater because radiant brooders have a larger radiant element: this fact combined with the fact that the radiant brooders can be mounted high off the floor creates a large radiant zone. According to University of Georgia Cooperative Extension data, this zone can be as wide as 40 feet in diameter resulting in large, loosely packed circles on cold winter mornings. Radiant brooders are often installed by poultry equipment dealers. However, there were some MAESTRO participants who replaced pancake heaters with radiant brooders without additional assistance from professional installers.

Insulation

Proper insulation of a poultry building is imperative to maintaining a proper temperature. Poultry producers can make a large impact on their facilities by sealing air leaks and insulating poultry houses to adequate R-Values. According to MU Guide G1107 Ventilation for Warm Confinement, there are several different recommended R-values for poultry houses. The level of insulation depends on whether or not the poultry house includes artificial heat. For instance, in layer houses where there is no artificial heat, R values of 9-12 is recommended for walls and an R value of 16 is recommended for ceilings. In broiler houses where artificial heat is needed, an R value of 13 is recommended for walls and an R value of 24 is recommended for ceilings.

Proper insulation and lack of air leaks are crucial as poultry producers strive for consistent temperature and humidity inside poultry houses. Producers often seal small air leaks with foam insulation. Proper insulation is needed in walls and ceilings in tunnel ventilated houses. In tunnel ventilated poultry houses, fresh air is brought into the house through large openings on the opposite end. Air is drawn through these opening and then down the house. It is then expelled through strategically placed outlets or fans. Tunnel ventilated or solid wall houses are more energy efficient than conventional poultry houses with curtains due to the ability to insulate along walls and the lack of air leaks around curtains.

In poultry houses that have not converted to tunnel ventilation, installation of insulated curtains is crucial to keep out winter winds and cold temperatures. Additionally, it is important to make sure curtains fit snugly against walls to avoid air leaks around curtains. Poultry producers should also take care not to forget to insulate properly in the wall around curtains. By properly insulating throughout the house, poultry producers can still save significant energy costs with curtain-ventilated poultry houses.

The MAESTRO program had both poultry producers who owned tunnel ventilation houses and those who owned curtain-ventilated houses. Thirty one percent of the poultry producers who installed energy efficient measures as part of the MAESTRO program sealed air leaks and added insulation to their building envelope. By installing this energy efficient technology, they saved an average of $1,775.91 per year on propane energy costs.

Average Building Envelope Insulation Savings Per Farm

Propane Savings	Dollar Savings Per Year	Installed Cost
13,837 gallons	$1,775.91	$10,833.10

Due to the declining number of curtain-ventilated poultry houses, a lower percentage of poultry producers participating in the program replaced uninsulated curtains with insulated curtains in their poultry houses. Nine percent of the poultry producers who installed energy efficient measures as part of the MAESTRO program installed insulated curtains to their poultry houses. By installing this energy efficient technology, they saved an average of $1,155.33 per year on propane energy costs.

Average Insulated Curtain Savings Per Farm

Propane Savings	Dollar Savings Per Year	Installed Cost
725 gallons	$1,155.33	$2,796.27

Another area of insulation that is often overlooked is on foundation walls of poultry houses. It is important to make sure concrete walls are covered with either foam insulation or soil to avoid heat loss. Typically foundation walls consist of concrete blocks. An eight-inch concrete block wall has an approximate R value of .64. Adding some type of insulation to your foundation wall is highly recommended.

How to Determine Need for Energy Audit

Poultry producers considering an energy audit may wonder how they can determine if an audit is really needed for their particular operation. There are four basic questions they can ask themselves. If they can answer yes to any of the questions below, an energy audit may be in order.

1. Has equipment recently been added to the farm?
2. Are there new industry developments or technology that's more efficient?
3. Has farming operation grown or expanded to include new property?
4. Is there an opportunity to apply for financial assistance (grant, loan or cost-share)?

For more information, visit http://extension.missouri.edu/energy. This site provides access to tools developed by MU Extension that will allow producers to conduct self evaluations to assess potential energy loss/inefficiency on their specific type of farming operation.

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Notes

Original work created by Montana State University Extension and the University of Wyoming.

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E^{3}A: Energy Management for Farm & Ranch

Energy Management for Farm & Ranch

Energy Conservation and Efficiency in Shops

Energy Series Information: *This publication is one in a series of Farm Energy Conservation guides that discusses energy savings on the farm. Data in this series were obtained through the Missouri Agricultural and Energy Savings Team – A Revolutionary Opportunity (MAESTRO) Program. The MAESTRO program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. Specifically, participants in the program were livestock producers who were not required to be permitted as confined animal feeding operations (CAFO). MAESTRO was a grant-funded program that provided cost-share assistance to implement energy efficient practices recommended in energy management plans though low-interest loans and rebates. Although these guides refer to energy savings in Missouri, many of the concepts described may apply to operations throughout the Midwest. If you are interested in more energy savings recommendations, please visit http://extension.missouri.edu/energy.*

Energy losses in farm shops resemble the energy losses in homes. However, we often ignore these losses. While it is true that the farm shop is usually not heated to as high a temperature as the home and it is usually not heated constantly, we can still achieve energy savings in the shop by applying some energy conservation and efficiency practices.

The first step to consider is to obtain an energy audit. This is especially true if you feel you have large energy use in the shop. The energy audit for a farm shop is similar to an energy audit for a home. An energy audit is an in-depth examination of a farm that determines: If/how energy is being lost, which systems are operating inefficiently, and what type of cost-efficient measures can be put into place to make the farm more energy efficient. To explain further, an energy audit evaluates a shop's current energy usage, makes calculations of existing systems' efficiency, and compares it to proposed new systems. Based on these calculations, an Agricultural Energy Management Plan (AgEMP) is created to explain what energy savings measures are recommended for the shop. AgEMP reports may qualify for financial assistance from various funding sources, which includes but are not limited to federal grants, loan programs, and/or energy tax credits.

As stated earlier, the MAESTRO program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. Data below that is shared on energy saving potential for shops were obtained through this program. Sixty farms representing beef, swine and dairy operations had their shops evaluated for energy savings. The energy savings came from updating lighting, insulating and sealing the shops from air leakage and changing to more efficient heaters. Of the sixty farm shops evaluated, the projected electrical savings were 88,160 kwh. The total estimated energy reduction for all the shops was 783.48 million BTUs. The installed cost of the recommended practices was $228,358.49. Estimated total savings was $23,464.97. The estimated payback was 9.7 years. On the average, each shop would see an annual savings of energy use of $391. Each shop would have an average investment of $3,806. Below is a chart representing the average savings per farm.

MMBtu Savings	Installed Cost	Savings Per Year	KWH Saved Per Year
13.058	$3,806	$391	1,469.01

Practices that have been typically found in AgEMPs for shops to help conserve energy and save on energy costs are listed below. These practices were identified through the MAESTRO Program.

Low to No Cost Energy Saving Practices

- Seal leaks anywhere that air can leak into the building.
- Turn down or turn off heat when the shop is not in use.
- Turn off lights when not in use. Consider motion detectors to automatically turn off lights when no one is working in the shop.
- Seal leaks in compressed air systems. Leaks cause the compressor to run more often, wasting energy.

Medium Cost Energy Saving Practices

- If insulation levels are low, consider adding insulation to the shop. You should consider R-values of 15 to 20 in the side walls, 30 in the ceiling and 10 in doors.
- If doors and windows are in poor condition, consider replacing them. Adding storm windows can also help reduce energy loss.
- Consider using zone heating and only heat the area in which you are working. This can be accomplished with various kinds of heaters that will heat the area where you are working.
- If you are using incandescent lights or inefficient fluorescent lights, consider replacing with more efficient lighting.

For more information on lighting, consider these resources. Energy Fundamentals for Farm Lighting: http://farmenergy.exnet.iastate.edu/wp-content/uploads/downloads/2012/02/PM-2089N.pdf and Farm Lighting EnergyEnergy Efficiency Checklist and Tips: http://www.extension.org/pages/32591/farm-lighting-energy-efficiency-checklist-and-tips

High Cost Energy Efficiency Practices

- Replace heating systems. This is most practical when the existing system is near the point it will need to be replaced because it is likely to fail. Consider using waste oil heaters or other renewable energy sources that could be produced on the farm.
- Adding insulation could fit into high cost options depending on how much and what type of insulation you need to add to your shop.

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Farmstead Energy Audit, North Dakota State University, http://www.ag.ndsu.edu/pubs/ageng/structu/ae1366.pdf

Conserve Heat Energy in the Farm Shop: Iowa State University, http://farmenergy.exnet.iastate.edu/wp-content/uploads/downloads/2012/02/PM-2089P.pdf

Farm Shop Energy Efficiency Checklist and Tips, http://www.extension.org/pages/30409/farm-shop-energy-efficiency-checklist-and-tips

Notes

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Appendix G

EnSave Fact Sheets / MAESTRO Best Practices Guide

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▶ Brood Curtains

Low-Cost Tips

- ☑ Check brooding curtain for holes or tears, and patch them.
- ☑ Install a steel pipe in the bottom of the brood curtain to create a tight seal with the floor of the house.
- ☑ Make sure the houses are well-sealed and insulated, especially in the brood chamber.
- ☑ Position bird boards a foot or so toward the non-brooding end of the house for a tighter seal between the curtain and the walls.

MAESTRO Achieved Fuel Savings by Using Brood Curtains

- ■ 5,798 gallons of propane saved each year

IT IS VERY IMPORTANT to maintain a high temperature in the poultry house when chicks first enter the house. Chicks like a temperature of approximately 95° F for the first 8-14 days in the house. This time period is critical to developing the skeletal structure, white meat, vascular system, digestive system, and immune system of the birds. If a house is under-heated, the birds will use all of the energy from their feed for body heat instead of using the energy for structural development, inhibiting the growth of the birds.

Heating an entire poultry house to 95° F requires a lot of fuel. Most farmers close half of the house off with a brood curtain, only using half of the house for the first 8-14 days. This greatly reduces fuel consumption in the brooding period. For a brood curtain to be effective, it needs to create a tight seal against the walls, floor, and ceiling of the house. Any loose seals or tears in the curtain will allow cold air to leak into the brood chamber, increasing the amount of fuel used to keep the house at the required temperature.

Comparing Regular Brood Curtains with Insulated Curtains

Regular brood curtains have little insulative value (R-1). Insulated brood curtains have more insulation (R-2.5). An insulated brood curtain is a cost effective way to further reduce fuel usage during the brooding period. They are more expensive than uninsulated brood curtains, but the reduction in fuel usage will more than pay for the insulated curtain over the life of the brood curtain. Typical paybacks for an insulated brood curtain are about two years.

PHOTO COURTESY NAICD

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Compressor Heat Recovery

Benefits of Compressor Heat Recovery Units

- ☑ Cools milk faster
- ☑ Improves long term milk storage
- ☑ Extends the life of the refrigeration system
- ☑ Can cut water heating costs by approximately 50%, depending on the size of the farm

Source: National Food and Energy Council (NFEC), www.nfec.org

MAESTRO Achieved Savings from the Use of Compressor Heat Recovery

- 72,892 kWh saved each year
- 3,242 gallons of propane saved each year

How does Compressor Heat Recovery work?

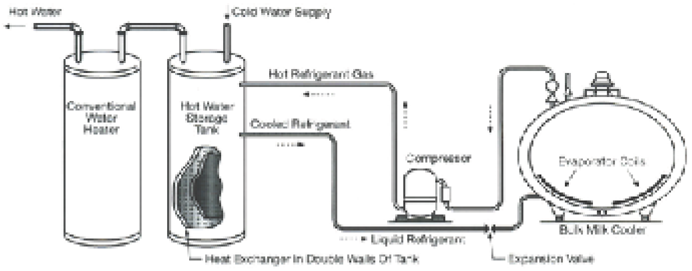
The process of cooling milk in a bulk tank or with a chiller utilizes one or more compressors to remove heat from the milk. Heat removed in this fashion is typically released into the air by condenser fans. A compressor heat recovery unit captures this "waste heat" and uses it to pre-heat water. Sometimes this removal actually improves compressor performance as well. A compressor heat recovery unit looks like a water heater tank and is capable of raising cold water to very warm temperatures of approximately 110° F.

Energy Savings

With a compressor heat recovery unit in place, the water heater has much less work to do. Since the incoming water is already preheated, the electric or gasfired water heater gets less use, and it is likely to last longer as well. Often a compressor heat recovery unit is a very cost effective piece of energy saving equipment that can be installed on a farm.

Example

A dairy farm uses 225 gallons of 160-degree water each day to wash milk lines, milking units, and the bulk tank and to mix calf feed. Their well water temperature is 55 degrees. They have a 120-gallon electric water heater and they pay $0.10 per kilowatt-hour (kWh) for their electricity. The farm will save 13,780 kWh and $1,378 each year by installing compressor heat recovery. Larger operations can expect to see even greater savings.



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▶ Milk Pump Variable Speed Drive

Why Should I Install a VSD on my Milk Pump?

- Milk will cool faster due to a constant flow rate through the plate cooler.
- Faster milk cooling inhibits growth of bacteria, preserving milk quality and flavor.
- Lower bacteria counts often deliver higher milk premiums.
- Shorter compressor run times mean lower electric bills.
- Integrated phase converter variable speed drives are available for single phase applications.

MAESTRO's Savings from Using a Milk Pump Variable Speed Drive

- **17,955 kWh saved each year**

Value of Milk Pre-Cooling

The speed of milk flow to the bulk tank is an important consideration in the milk cooling system design. Milk pre-cooling is widely used to maintain milk quality by cooling the milk quickly, reducing bulk tank compressor run time, and saving on electricity costs. Plate-type milk pre-coolers utilize cold water in a heat exchanger to absorb heat from the warm milk before it goes to the bulk tank. The efficiency of the plate cooler depends on the temperature of the cold water, the ratio of cold water to warm milk flowing through the unit, and the rate of flow of the milk. Plate coolers are sized to accommodate the volume of milk being pumped to the bulk tank.

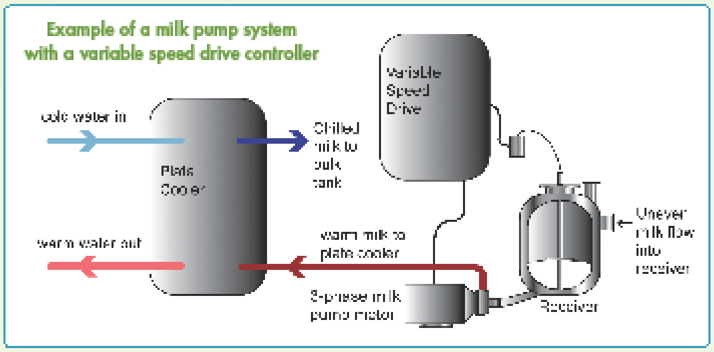
How Does a Milk Pump VSD Work?

Another factor in plate cooler efficiency is the evenness of the flow of milk through the unit. With standard milk pumps the milk can gush or trickle into the plate cooler, reducing heat exchange efficiency. A variable speed drive (VSD) produces a steady flow of milk through the plate cooler and optimizes cooling. This improved performance reduces cooling costs in the bulk tank and helps maintain milk quality.

The milk pump VSD can reduce the temperature of the milk entering the bulk tank to within 4° F of the incoming cold water temperature.

Significant Savings

Typical energy savings of 30% can be realized by reducing the run time of the bulk tank compressor when a plate cooler is used in conjunction with a milk pump VSD.



Example of a milk pump system with a variable speed drive controller

▶ Milking Vacuum Pump Variable Speed Drive

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What Does a Variable Speed Drive Do?

The Variable Speed Drive is a digital controller that regulates the speed of the milking vacuum pump.

Integrated phase converter variable speed drives are available for single phase applications.

MAESTRO's Savings from Using Milk Vacuum Pump Variable Speed Drives

- 184,888 kWh saved each year

VSD operation

Milking vacuum pumps are sized to deliver the required maximum vacuum level to operate the milking and washing systems. Occasionally, when a milking unit falls off a cow's udder or when there is a temporary system leak, high levels of vacuum are needed for short intervals. Normal milking operation uses less than half the maximum vacuum available. Before variable speed technology was used for vacuum pumps, dairy operators had to run their pumps at a constant high speed to perform adequately during the occasional short intervals of high vacuum need. The VSD determines exactly how much vacuum the system requires and regulates the speed of the pump. The result is a pump that runs at a much lower speed most of the time and requires substantially less electricity to do the job.

Stable vacuum

A constant vacuum level at the milking units is necessary to prevent bacteria from accessing the cows' teats. A VSD reacts quickly and maintains a stable level as well or better than conventional systems.

Equipment life

A motor run at full speed will have a shorter life span than a motor that regularly runs at a lower speed. Since the VSD operates the vacuum pump at reduced RPMs, bearings and other internal components last longer and require less frequent maintenance. Pumps will require less frequent replacement.

Noise reduction

Conventional milking vacuum pumps running at full speed make a lot of noise. Many farmers benefit from significantly quieter milking areas.

Great financial investment

The energy and money savings from installing a VSD varies from farm to farm, based on the size and type of vacuum pump, the type of milking system, and the milking time. On some dairy farms, the substantial energy savings have made the payback period on the installed cost of the VSD as short as three years. Quick payback makes the VSD one of the best investments a dairy farmer can make.

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▶ Milk Pre-Coolers

Benefits of Using Milk Pre-Coolers

- ☑ Extends refrigeration equipment life by reducing load and run time.
- ☑ Increases milk quality by inhibiting bacterial growth through faster cooling.
- ☑ Saves electricity and money with faster cooling and shorter compressor run time.
- ☑ Daily milk production can also be increased when the warm water exiting the Pre-Cooler is used for stock watering.

Special Considerations

- ☑ Work with your equipment dealer to ensure that your water supply meets your cooling needs.
- ☑ Water used in Milk Pre-Coolers must meet all local Health Department quality requirements.

MAESTRO's Savings from Using Milk Pre-Coolers

- 68,784 kWh saved each year

How do Milk Pre-Coolers work?

Milk typically comes from the cow at about 98° F, and in dairy operations without milk pre-cooling, flows into a receiver, and is then pumped into the bulk tank. Compressors cool the incoming milk in the bulk tank to a storage temperature of about 38° F. The milk pre-cooler, often called a plate cooler, is a series of stainless steel plates installed in the milk line before the bulk tank. Cold water passes through a plate cooler in one direction and absorbs heat from the warm milk pumped through the plate cooler in the opposite direction. The plate cooler can reduce the temperature of the milk entering the bulk tank to within 4° F of the incoming cold water temperature.

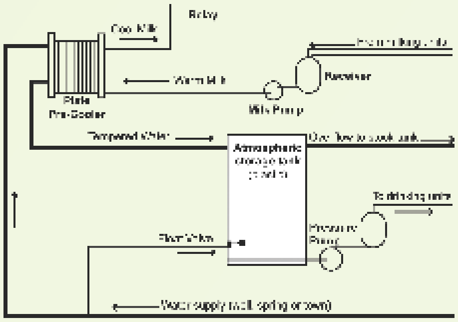
Performance Factors

Milk pre-cooler effectiveness depends on several factors. Colder water removes more heat than warmer water. The ratio of water volume to milk volume moving through the plate cooler also affects performance. Setting up the cooler to use twice as much water flow as milk flow is common. The greater the ratio, the more pre-cooling occurs. A third factor is the velocity of the milk moving through the cooler. The slower milk goes through the plate cooler, the more heat can be removed.

Energy Savings

Milk cooling costs are usually one of the largest energy operating expenses for dairy producers. For example, a dairy farm that produces 3,000,000 pounds of milk per year and uses 112,000 kilowatt hours (kWh) of electricity at a cost of $0.10 per kWh can save as much as $800 (8,000 kWh) a year if a plate cooler is installed.

Milk Flow Process with Plate Cooler



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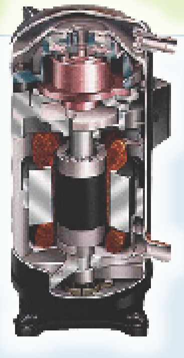
▶ Scroll Compressors on the Dairy Farm



Reasons to Upgrade to a Scroll Compressor

- Save energy and money
- Quieter milking environment
- Require virtually no maintenance
- Last longer than other compressor types
- Deliver consistent cooling

The scroll compressor relies on dual spinning scrolls that compress refrigerant. As the scrolls spin they create ever-smaller gas pockets and generate greater pressure. Suction is continuous and pulse-free because all gas pockets are in various stages of compression at all times. There are no intake, compression, or exhaust strokes typical of conventional reciprocating compressors that cause vibration and noise.

MAESTRO's Savings from Using Scroll Compressors

- **34,678 kWh saved each year**

Dairy producers know the importance of cooling their milk quickly and keeping it cool until it is picked up. For many years reciprocating compressors have cooled milk in America's bulk tanks. Whether single or double acting, these reciprocating compressors historically have used a lot of electricity, required regular maintenance, and tended to be very noisy. It is now possible to replace an aging reciprocating compressor with a new scroll compressor and experience several benefits from the switch.

What the Scroll Compressor Offers

Uses Less Energy Scroll compressors require much less current than conventional reciprocating compressors and are even able to run on single-phase electricity. One study found that a 3-hp scroll compressor used 42.1 percent fewer kilowatt-hours than a 3-hp reciprocating compressor over a 36-day period (72 milkings).

Runs More Quietly Working in the milk house will be easier on your ears. Since there are only four moving parts (no pistons or discharge valves), scroll compressors run at lower decibel levels and vibrate less than reciprocating compressors. Under load the scroll compressor is quieter than a household clothes washer (approximately 65dBA with enclosure).

More Durable and Reliable With only four moving parts and no metal-to-metal contact, there are no seals to tear and no lubrication needed. Another important feature is that scroll compressors operate well in cool weather and do not require crankcase heaters. Finally, scroll compressors can start under any system load so there is no need for a start kit.

Better Control Over Milk Quality It is crucial to keep milk cooled at a consistent temperature to prevent high bacteria counts. In fact, if the temperature is always kept low, mastitis-causing bacteria such as staph aureus and strep ag tend to nearly cease growing. A scroll compressor delivers the consistent, dependable cooling necessary to sustain these beneficial conditions in the bulk tank.

Competitively Priced and Easily Available Several manufacturers produce scroll compressors that are sold through farm and dairy equipment suppliers. Installation costs are comparable to conventional reciprocating compressors. replacement options.

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Energy Efficient Stock Waterers

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Did You Know?

Several factors determine how much water a cow will drink: her size, milk yield, quantity of dry matter consumed, temperature of the environment as well as the water quality, availability of the water, and amount of moisture in her feed.

For horses, bison, and other livestock, a primary waterer selection factor is the frequency of use. With minimal usage the waterers need to be better insulated and equipped with reliable heaters to ensure the floating cover does not freeze in place, preventing the animal from drinking.

MAESTRO Achieved Savings from Using Energy Efficient Stock Waterers

- **104,068 kWh saved each year**

The Need for Reliable Stock Watering

All livestock need access to drinking water. In northern climates keeping water from freezing in unheated barns and outdoor settings is critical. This need has usually been met by heating drinking water with an electric heater that often draws 1000 to 1500 watts.

The Energy Efficient Alternative

Well insulated, all plastic stock waterers have proven their ability to keep drinking water from freezing using 250 watts of electricity or even no electricity at all. One of the keys to making the energy-efficient and energy-free models work is proper sizing for the number of animals served. Since ground water temperature is usually around 50° F, air temperature must drop about 20° F to reach the freezing point.

If enough animals drink from the waterer, the incoming "warm" water will keep the unit from freezing. Proper insulation of the unit keeps this heat in the waterer. Many of these units have floating plastic covers which float on the water and seal the opening of the watering reservoir when animals are not drinking.

Not all sites are suitable for energy-free models. It is particularly important to assure that electrical wiring not come in contact with livestock drinking water to prevent electric shock to animal or farmer.

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Missouri Agricultural Energy Saving Team — A Revolutionary Opportunity

Best Practices Guide

Energy Savings Opportunities for Missouri Livestock Farmers

Inside the Guide

Welcome to MAESTRO's Best Practices Guide.

The MAESTRO program was created to strengthen the financial viability of Missouri's livestock producers through energy efficiency. The project focused on producers not required to be permitted as confined animal feeding operations by helping them implement energy efficient technologies for both the production facilities and the homes on those farms.

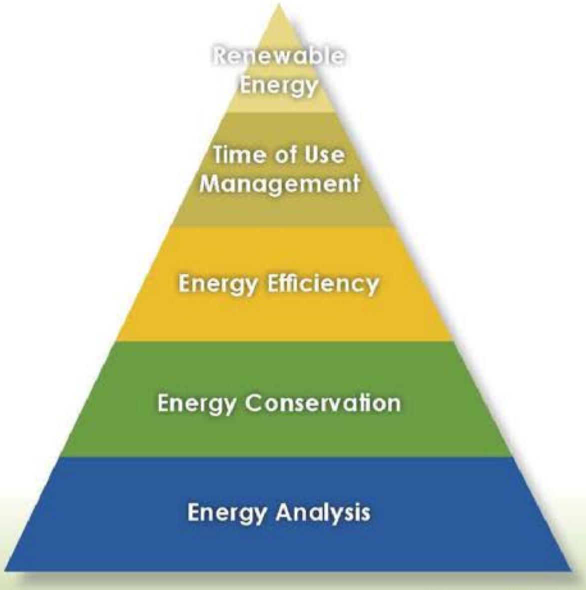
Financial incentives were made available for both energy assessments, technical assistance, and for implementing recommended energy saving practices. The program was delivered through the Missouri Department of Agriculture in collaboration with the University of Missouri Extension and EnSave, Inc. Funding was provided by the U.S. Department of Energy through the American Recovery and Reinvestment Act.

The following pages outline the most common practices implemented throughout the life of the program and educational information about those measures. **The MAESTRO team has prepared this guide to help Missouri farmers continue on the path toward energy independence.**

The Energy Pyramid

The energy pyramid is a useful concept designed to help people understand the process of using energy efficiently. Rather than being the first course of action, renewable energy should be considered only after a farm has considered all other steps of the pyramid.

The energy pyramid illustrates the steps in the process of becoming more energy independent, from the simplest and least expensive technique to the most complex.



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RENEWABLE ENERGY

The last step on the energy pyramid is renewable energy, which is generating your own energy from naturally replenished sources for use on the farm. Examples include solar power, wind power, methane digesters and hydroelectricity.

TIME OF USE MANAGEMENT

Electricity costs can vary over the course of the day. Running equipment during peak hours can be costly. By running equipment during off-peak hours, money and energy can be saved.

ENERGY EFFICIENCY

The third level on the energy pyramid is energy efficiency, such as lighting an area with compact fluorescent lights versus incandescent lights. Work smarter and save money with more energy efficient equipment.

ENERGY CONSERVATION

The easiest way to conserve energy is to change current behavior: turn off lights if no one is using them, unplug unused equipment, and turn the thermostat lower in the winter and higher in the summer.

ENERGY ANALYSIS

This is the very first level towards reducing energy usage. By having an audit or assessment done (or doing an assessment on your own), opportunities to reduce energy use and costs can be identified.

Throughout this brochure, you will find helpful ideas that address each step of the pyramid.

Get in Touch

If you have any questions about the energy pyramid or would like to learn more about how these ideas can work on your farm or facility, contact your local University of Missouri Extension office or EnSave, Inc. at 800-732-1399.

Farm Energy Management Plans

The MAESTRO program provided more than 140 Energy Management Plans (EMPs) to Missouri farmers. The EMP analyzes current energy use for the whole farm operation and provides recommendations for energy conservation and energy efficiency. There is a tremendous opportunity on the farm to save energy and money by developing a cost-effective plan to upgrade or add energy efficient equipment.

PROGRAM STATISTICS FOR ENERGY MANAGEMENT PLANS

- 76 farmers received incentive money to implement energy efficient measures on their farms.
- $777,473 distributed to farmers to implement energy efficient equipment
- Energy savings from Energy Management Plans: 671,550 kWh annually
  - This equates to heating 604 homes in Missouri for one year
- Fuel savings from Energy Management Plans: 62,086 gallons of fuel per year

Technical Assistance Reports

Farmers who were interested in having one specific measure evaluated rather than the whole farm operation could receive a Technical Assistance (TA) report. The MAESTRO program completed 103 TA reports for Missouri farmers.

PROGRAM STATISTICS FOR TECHNICAL ASSISTANCE REPORTS

- 67 farmers received incentive money to implement a specific energy efficient measure.
- $432,111 distributed to farmers to implement an energy efficient equipment
- Energy savings from TAs: 416,448 kWh annually
  - This equates to heating 375 homes for one year
- Fuel savings from Technical Assistance Reports: 16,560 gallons of fuel per year

Farm Residence Audits

Farmers received recommendations on how to improve their energy use and save money on energy costs in their houses. More than 100 home energy assessments (audits) were performed for farmers that participated in the MAESTRO program.

PROGRAM STATISTICS FOR FARM RESIDENCE AUDITS

- 48 farmers received incentive money to implement energy efficient equipment.
- $303,798 distributed to farmers to implement energy efficient equipment at the farm residence.
- Energy savings from farm residence audits: 323,029 kWh annually and 43,641 gallons of fuel per year

> *"The MAESTRO program has been wonderful! We needed to make upgrades on our barn, and this program helped us do this. The changes are already making a difference—the insulated curtains, more efficient heaters and lights. Everything works together to help us save energy."*
>
> – JOANN SCOTTEN, SWINE FARMER

Poultry Measures

Radiant Heating

Radiant heaters are the most efficient means of heating a poultry house. Radiant heaters directly heat the objects in a house, allowing the air temperature in a house to be lower than the temperature of the objects.

Traditional forced hot air heaters and pancake brooders heat the air in a house. The heat in the air is lost when the air is changed in the house. Radiant heaters use between 15 percent to 30 percent less fuel than forced hot air heaters and pancake brooders when installed and managed properly.

In addition to being a more efficient heat source, radiant heaters have other distinct advantages compared to traditional poultry house heaters. Radiant heaters transfer heat directly to the litter pack, removing moisture and heating the litter so the birds do not lose heat through their feet. Radiant heaters can also be mounted higher in the house, eliminating the need to raise and lower the heaters. Radiant heaters also take less time to preheat a house.

Tunnel Ventilation Fans

Tunnel ventilation fans are exhaust fans located at one end of the poultry house. Two large air inlets are installed at the opposite end of the house. The fans draw outside air through the openings and down the length of the house, producing a wind tunnel effect. This is an efficient method of cooling down the birds during the warmer months and can be combined with evaporative cooling for increased temperature control.

The easiest way to select fans is to choose fans that have been run through standardized tests, such as the ones done by the Bioenvironmental and Structural Systems (BESS) Laboratory at the University of Illinois. BESS Labs tests fans with accessories such as shutters, guards, and cones to determine the efficiency of each fan. An energy efficient fan may cost more up front, but the lower operating cost will justify this cost over the life of the fan.

Maintenance and Safety Tips

- ☑ **Clean reflectors and heating elements between every flock**
- ☑ **Check gas lines for leaks between every flock**
- ☑ **Operate heaters at the specified gas pressure**

Low-Cost Tips

- ☑ **Keep fans clean and well maintained; dirty shutters and blades can decrease airflow up to 40 percent**
- ☑ **Check and maintain belt tension on fan motors**
- ☑ **Use cog-type fan belts, as they are typically 2% more efficient than v-belts**

Low-Cost Tips

- ☑ **Check brood curtain for holes or tears and patch them**
- ☑ **Install a steel pipe in the bottom of the brood curtain to create a tight seal with the floor**
- ☑ **Position bird boards a foot or so toward the non-brooding end of the house for a tighter seal between the curtain and walls**

Benefits of Good End Wall Doors

- **Seal air leaks, leading to less heating fuel use**
- **Higher insulation value, leading to less heating fuel use**
- **Less litter moisture**

Brood Curtains

Heating an entire poultry house during the brood period requires a lot of fuel. Most farmers close half the house off with a brood curtain, only using half of the house for the brood period, significantly reducing fuel consumption. For a brood curtain to be effective, it needs to create a tight seal against the walls, floor and ceiling of the house. Any loose seals or tears in the curtain will allow cold air to leak into the brood chamber, increasing the amount of fuel used to keep the house at the required temperature.

Regular brood curtains have little insulation value (R-1). Insulated brood curtains have more insulation (R-2.5). An insulated brood curtain is a cost effective way to further reduce fuel usage during the brooding period. They are more expensive than uninsulated brood curtains, but the reduction in fuel usage will more than pay for the insulated curtain over the life of the brood curtain. Typical paybacks for an insulated brood curtain are about two years.

End Wall Doors

End wall doors can be a significant area for heat loss if the doors are not in good condition. Warped, poor-sealing doors can allow air leaks, which negatively effect the temperature environment within the poultry house. This can lead to higher heating costs, litter caking, lower feed intake, lower feed conversion efficiencies and smaller birds.

A good door should be strong enough to withstand the elements, have a good seal to eliminate leaks, withstand the pressurization requirements of the poultry house, and have good insulating properties. Although end doors are only used twice per flock, good doors will save energy all year by reducing air infiltration and heat loss. A door that is durable, insulated and seals well is an excellent investment and will help save energy on the farm used to power multiple loads.

Controllers

Today's poultry houses require constant monitoring of temperature to maximize bird growth. Traditional controls use thermostats to control the heating and cooling systems in a house. Thermostats can often drift out of calibration, allowing for overheating and over-cooling. Water, feed and air quality also need to be constantly monitored. These can be overwhelming tasks for a poultry grower without the help of an electronic controller.

Controllers can coordinate heating, cooling, ventilation and lighting systems in an integrated fashion. The house can then maintain optimum growing conditions, maximizing the growth rate and feed conversion efficiency of the birds. Energy can also be saved by avoiding overheating or over-cooling.

Controllers are PC compatible, so regular reports on temperature, feed and water conditions, and even bird weights can be sent directly to the office computer. The data can then be analyzed for trends and trouble areas. Alarms can be set on the controllers to alert a farmer when undesired conditions occur in the poultry house.

> *"The whole process has been great. I've saved lots of money, and my flocks have gotten a lot better; even the bird quality is better. This has been more than just energy savings. The audit was able to let me know what things I could put in and change in my barns to help save money and energy."*
>
> – WAYNE HENTGES, POULTRY FARMER

Benefits of a Controller

- **Controllers can make immediate adjustments to house conditions**
- **Money, energy, and time saved**
- **Provides an alarm system to alert you to serious conditions**
- **Helps maintain optimum growing conditions to maximize profit and bird comfort**

Dairy Measures

Plate Coolers

Milk typically comes from the cow at about 98° F, and in dairy operations without milk pre-cooling, flows into a receiver, and is then pumped into the bulk tank. Compressors then cool the milk to a storage temperature of about 38° F.

A milk pre-cooler, or plate cooler, is a set of stainless steel plates installed in the milk line before the bulk tank. Well water passes through the plate cooler in one direction and absorbs heat from the warm milk pumped through the plate cooler in the opposite direction.

Milk cooling costs account for some of the greatest energy expenses on a dairy farm. By using a pre-cooler, a dairy farm that produces 3 million pounds of milk per year can save about $800 annually.

Milk Transfer Pump VSD

When using plate coolers, which use either glycol or ground water to absorb heat from the milk before transferring it to the bulk tank the plate cooler's efficiency depends on the cold water temperature and flow rates of both the milk and the water.

Standard milk pumps can't provide a constant flow of milk into the cooler, reducing the efficiency. A variable speed drive (VSD) on the milk transfer pump will produce a steady flow of milk through the plate cooler, optimizing cooling.

This improved performance reduces cooling costs associated with bulk tank compressors while maintaining milk quality. Tests have shown an average energy savings of 30% on the run time of the bulk tank compressor when the milk pump is controlled by a VSD coupled with a plate cooler.

Benefits of a Plate Cooler

- ☑ **Extends equipment life by reducing load and run time**
- ☑ **Increases milk quality by inhibiting bacterial growth**
- ☑ **Saves electricity and money**

Low-Cost Tips

- ☑ **Conduct regular maintenance, including cleaning evaporator and condenser coils**
- ☑ **Check insulation on supply and return refrigerator lines and re-insulate where appropriate**

Benefits of a Milk Vacuum Pump VSD

- **Cuts electricity use**
- **Maintains a constant vacuum level**
- **Provides a quieter working environment**

Milk Vacuum Pump VSD

A Variable Speed Drive (VSD) is a digital controller that regulates the speed of the milking vacuum pump motor. Before variable speed technology, dairy operators had to run their pumps at a constant high speed to perform adequately during the short intervals of high vacuum need.

The VSD measures how much vacuum the system requires and regulates the speed of the pump motor. The result is a pump and motor that work only as hard as they need to, which leads to substantial energy savings.

The energy and cost savings from installing a VSD vary based on the horsepower of the pump and the number of milkings. Many farms find a VSD to be a good investment.

Benefits of a Scroll Compressor

- **Saves energy and money**
- **Lasts longer than other compressors**
- **Cools consistently**

Scroll Compressor

For many years reciprocating compressors have cooled milk in bulk tanks. These compressors are inefficient, require regular maintenance, and are noisy. Scroll compressors use dual spinning scrolls to compress refrigerant. As the scrolls spin, they create ever-smaller gas pockets and generate greater pressure. Suction is continuous and pulse-free.

Scroll compressors use significantly less energy than reciprocating compressors. One study found that a 3-hp scroll compressor saved 41% more electricity than a 3-hp reciprocating compressor. They are also quieter. With only four moving parts and no metal-on-metal contact, there are no seals to tear and no lubrication needed.

They also work well in cool weather and can start under any system load. Installation costs are comparable to conventional reciprocating compressors.

Compressor Heat Recovery

When cooling milk in a bulk tank or with a chiller, compressors are used to remove the heat from the milk. The heat removed is usually released back into the air by condenser fans. By installing a compressor heat recovery unit, this otherwise wasted heat can be reused to heat water.

A compressor heat recovery unit can raise water temperatures as high as 110° F. Since the incoming water is pre-heated, the water heater has less work to do and will likely last longer as a result. In addition, these units can often help improve compressor performance.

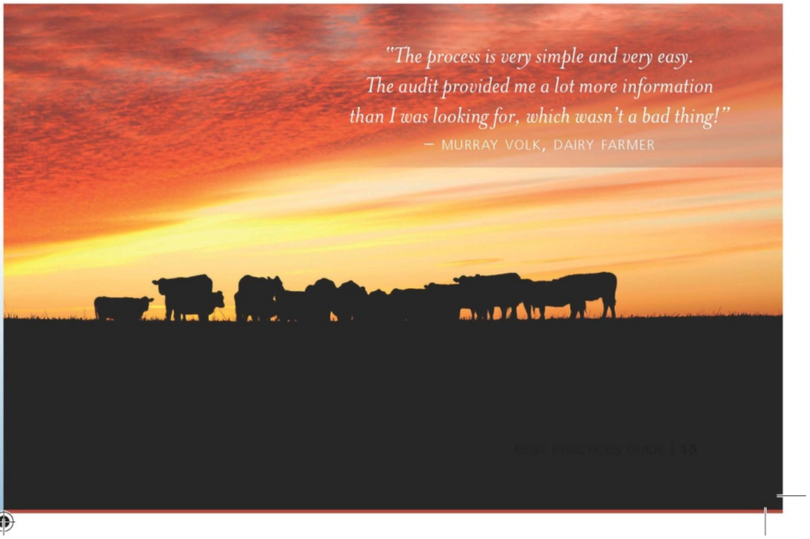
A compressor heat recovery unit can be one of the most cost effective purchases a dairy farmer can make. For example, a dairy farm using 225 gallons of heated water every day can save as much as $1,300 on their annual electricity costs. Larger farms could see even more savings.

Benefits of a Compressor Heat Recovery Unit

☑ **Can extend life of refrigeration system**

☑ **Improves compressor performance**

☑ **Cuts water heating costs by close to 50%**



> *"The process is very simple and very easy. The audit provided me a lot more information than I was looking for, which wasn't a bad thing!"*
>
> – MURRAY VOLK, DAIRY FARMER

Measures for Most Livestock

LED Lighting

Light-Emitting Diodes (LEDs) are an energy efficient lighting option for animal housing. They use about 15 percent of the energy that an equivalent incandescent light uses. LEDs last much longer than any other lighting option, with a useful life range of 40,000-50,000 hours. In poultry houses, LEDs have been proven to stimulate the birds to eat and drink better than under incandescent lights and CFLs. They may cost more initially than other lights, but they last longer and cost less to operate. LED lighting has superior dimming qualities to other lighting options and is capable of dimming to 0 percent with no flicker.

Before installing LEDs, check with your electrician or integrator to ensure adequate lighting levels are met and that LEDs are permitted within any growing contract. The American Society of Agricultural and Biological Engineers publishes "Lighting Systems for Agricultural Facilities," a standard that specifies the minimum lighting level recommended for different types of livestock. Check with your Extension specialist regarding appropriate lighting levels for other types of livestock. It is also important to have a dimmer that is compatible with LEDs. These steps will help facilitate a successful retrofit.

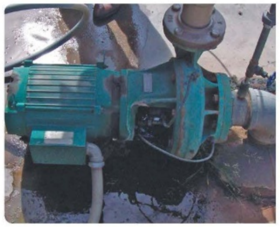
- ☑ **Choose lights specifically designed for your livestock**
- ☑ **Choose lights that come with a 3 year warranty or better**
- ☑ **Choose lights that have a color temperature between 3,500-6,400 Kelvin**
- ☑ **Check with you integrator to make sure LEDs are permitted**

Irrigation Pump Upgrades

Testing irrigation pumps for pumping efficiency is a good way of learning if they are working at their optimum efficiency, and can help determine if it is time for a pump upgrade.

Pump efficiency testing measures gallons pumped per minute, total dynamic head (pumping water level and operating pressure), and input horsepower. This information determines if the pump is working efficiently, or if it is time to upgrade. Prior to upgrading, consider the following:

- Upgrade to a premium efficiency motor. It will last longer and cost less to run. Use the right size motor for the job.
- Replace/repair the pump impeller/bowl.
- Properly adjust the impeller and bowl to ensure the proper amount of water is pumped.



Low-Cost Tips

- ☑ **Test well and pump at least every two years**
- ☑ **Inspect the well to ensure there is no clogging or corrosion**

Did You Know?

- **Many factors determine how much water an animal drinks, including size, milk yield, feed, temperature and water quality and availability**
- **With low usage, the waterers must be well insulated and have reliable heaters so the floating cover will not freeze in place**

Low-Cost Tips

- ☑ **Turn off lights when not in use**
- ☑ **Light work areas, not the entire building**
- ☑ **Use daylight when possible**
- ☑ **Install dimmable ballasts to control light levels**
- ☑ **Keep reflector shields and lenses clean**

Stock Waterers

In cold climates, keeping livestock drinking water from freezing during the winter is critical. Electrically heated stock waterers have traditionally kept water from freezing, drawing 1,000 to 1,500 watts of electricity.

However, well insulated, plastic stock waterers have proven their ability to keep drinking water from freezing using 250 watts of electricity or even no electricity at all. Since the year-round ground water temperature is about 56° to 58° F, the air temperature must fall to 20° F to freeze solid. If enough animals drink from the waterer, the incoming water will keep it from freezing.

The unit's insulation helps to keep the heat in the water. Many units have plastic covers that float on the water and seal the opening of the reservoir when not in use. Not all sites are suitable for the energy-free models.

Efficient Fluorescent Lighting

Incandescent light bulbs are inefficient, converting only 10 percent of the energy they use to light, with the rest wasted as heat. There are many types of fluorescent lights available that are much more energy efficient.

Compact Fluorescent Lamps (CFLs) deliver the same amount of light as incandescent bulbs, but use only 1/4 of the electricity. Installing CFLs may cost a little more initally, but they can last up to 10 times longer. Cold Cathode Fluorescent Lamps (CCFLs) can last up to 25 times longer and have around the same efficiency as CFLs.

T-8 and T-5 lights with electronic ballasts replace the older T-12s and have several benefits. In addition to using about 20 percent less energy, the T-8 and T-5s generate less noise, more light per watt, better color rendering, minimal flickering, cooler operation, and provide electric cost savings.

Ventilation

Heat and moisture build-up can adversely affect the health of animals and humans. Research has shown that inadequate barn ventilation can result in a production drop of 6 to 14 pounds of milk per cow per day.

Most agricultural ventilation systems rely on exhaust fans to remove moisture build-up. A good ventilation system should provide a sufficient number of air changes in the barn per hour for the type of livestock present. Properly sized and located air inlets are necessary for an effective and efficient system. Research indicates that milk production is optimized at an ambient air temperature of about 48 degrees Fahrenheit.

Fans from different manufacturers differ markedly in air delivery and energy efficiency. When upgrading or replacing existing fans, be sure to use the most efficient fans possible.

Insulation/Sealing Air Leaks

Insulation works by reducing heat transfer from one area to another.

In winter, insulation reduces the transfer of heat from inside the building to the outside air, helping the building stay at warmer temperatures. In summer, insulation reduces the transfer of heat from outside the building to within the house, helping the house stay at cooler temperatures.

Insulation helps regulate the temperature within a building, reducing the need of supplemental heating and cooling.

Low-Cost Tips

- ☑ **Clean fan blades, motors and controls**
- ☑ **Lubricate pivot points of shutters and inlets**
- ☑ **Check all wiring from service entrance box to point of use**
- ☑ **Check pulleys and belts for proper tension and alignment**

Low-Cost Tips

- ☑ **Clean circulation fans with a brush or leaf blower on a regular basis**
- ☑ **Keep basket fans parallel with the ceiling to properly move the warm air along the ceiling**
- ☑ **Use paddle fans in the updraft mode**

Circulation (Stir) Fans

Circulation fans have been found to be effective at mixing the air in confined animal buildings to create more uniform temperatures. Circulation fans are used to recirculate warm air from the ceiling to floor level where the animals need it.

Warm air rises to the ceiling of an animal building, trapping itself out of reach of the animals. A properly designed and installed circulation fan system will move warm air from the ceiling to the floor without creating enough air flow to chill the livestock.

Fans for air recirculation often do not need to be large or powerful, and there are several types of fans that will work. Some common types used are 18" basket fans and 48" paddle fans for poultry and swine houses and larger (20' diameter in some cases) for dairy loafing sheds. Benefits of recirculating the air include reduced fuel use, less wear and tear on the heating equipment and decreased bedding moisture. Both open and closed ceiling houses can benefit from adding circulation fans to more evenly mix the air in a building.

High Pressure Sodium Lighting

High pressure sodium lighting is an excellent choice for barn yards and other exterior areas. These yellowish lights are also suitable for indoor areas where color rendition is not important.

High pressure sodium lights are long lasting with an expected life of about 24,000 burning hours or six years for photo-controlled fixtures. They are very energy efficient and produce more lumens per watt than mercury vapor bulbs.

Units inside barns should be wired to a common photocell in a bright area to minimize operating hours. Indoor fixtures should also have enclosed and gasketed optics to protect the lamp and reflector, and increase the life and light output of the fixture, as well as reduce the time required to clean the fixture as only the lens will need to be cleaned.

NEMA Premium® Motors

When installing a new motor or replacing an old motor, consider using a NEMA Premium® motor. While they may cost more initially, they are often cheaper to operate in the long run.

When purchasing a new motor, take into account the length of time the motor will run, how high electric bills currently are, and the right sized motor for the job. If the motor is only running sporadically, a retrofit to a NEMA Premium® motor may not make sense. However, the longer the motor runs, the greater the potential for savings. In new installations, NEMA Premium® motors are the standard.

Premium efficiency motors are usually made to higher manufacturing standards, and stricter quality controls. For more information, visit: www.nema.org/gov/energy/efficiency/premium/

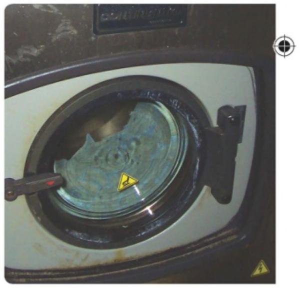
Energy Star® Qualified Washers

Dairies do several loads of laundry a day, so there is energy savings potential from switching to an Energy Star® clothes washer. Energy Star® is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy that helps save money and protect the environment with energy efficient products. Energy Star® qualified washers use 40 percent less energy than standard washers. Most full-sized Energy Star® washers use 18–25 gallons of water per load, compared to 40 gallons used by a standard machine. They also extract more water during the spin cycle, which saves energy by reducing drying time and wear and tear on fabric.

> *"The process was painless. It showed me ways to save on my gas bill, and by saving on my gas bill, I will save on my electric bill"*
>
> – KENNY DEIBEL, SWINE FARMER

Low-Cost Tips

- ☑ **Select the right size motor for the job**
- ☑ **Inspect all motors on a regular basis**
- ☑ **Clean motors regularly**
- ☑ **Replace V-type belts with notched belts**



To buy an Energy Star® qualified washer, just look for the Energy Star® label or go online and review the list of qualified washers at: www.energystar.gov.

To reduce your electric demand, consider:

- **Moving certain operations to off-peak periods**
- **Avoiding having all equipment running at the same time**
- **Making sure your equipment is properly sized for the need**
- **Implementing electronic controls**

Understanding Demand Charges and Time of Use

Electric demand is the rate at which electricity is being used by a consumer at any given time, and is measured in kilowatts (kW). The electric utility is concerned about the peak demand because it must maintain power quality with appropriate equipment and capacity to meet this peak. The consumer's peak demand during the month is based on a moving 15-minute average for that month.

To pay for the generation and transmission capacity to meet peak demand, utilities charge their larger energy users a demand charge based on the single highest 15-minute demand period measured in a month or a specified time period.

Some utilities have different demand rates based on the time of day when the peak occurs. The higher demand rates are for periods of the day when the utility sees higher demand. Since this demand is based on when the energy is used, there may be opportunities to reduce demand charges by better managing the time period in which equipment is used. This is called "time of use management."

Reducing demand not only saves money, but also helps the environment. When utilities do not need to generate as much power, they avoid needing to increase capacity through building new power plants or purchasing more energy from other suppliers. While an energy audit explains where energy is being used, if demand charges are a concern for your farm you may benefit from a more detailed analysis. To learn about how time of use management can help your farm save money, contact your electric utility/cooperative or call EnSave, Inc. at (800) 732-1399.

Tractor & Implement Maintenance

Regular maintenance and other practices will help tractors perform more efficiently and reduce fuel use. Consider integrating these fuel saving ideas into a regular maintenance schedule:

- Replace air and fuel filters regularly
- Check tire pressures frequently, and replace worn tires
- Use proper ballast for each operation
- Do not idle diesel engines more than 10 minutes
- Clean dirty fuel injectors
- Keep ground-engaging tools sharp
- Use the right tractor for the job (match the horsepower to the load)
- Combine trips whenever possible

Preventative Maintenance

- Remove dust, soot and debris from equipment to allow it to do more work with less effort, extending its life and reducing energy usage.
- Equipment should be checked regularly. Replace parts that are showing excessive wear before they break and cause irreparable damage.
- Leaks in any fluid system waste energy and money. Regular inspection helps identify leaks and keeps your fluid systems running efficiently.

> *"MAESTRO worked very well for our operation. It was easy to access someone in the program when we had a question or needed to discuss our farm."*
>
> – TED STUBER, DAIRY FARMER

Gear Up/ Throttle Down

If using a high horsepower tractor while pulling lighter loads, fuel can be saved by running it in a higher gear and a lower engine speed. Stay within the engine RPM working range as specified in the operator's manual, and do not overload the engine.

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Extension

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RECOVERY.GOV

Thank you to the Missouri Department of Agriculture and EnSave, Inc. for the photos in this guide.

Appendix H

EnSave Audit Ranking Guides

Audit Ranking Guide

EnSave

65 Millet Street, Richmond, VT 05477
802-434-3792

POULTRY HOUSING- BROILERS/TURKEY, 2 OR MORE HOUSES

Are you currently permitted as a Confined Animal Feedlot? (CAFO) Yes/No If yes, audit is not applicable			
Do you have at least 6 inches of insulation in/on your ceilings?		0	
Do you have curtain walls?			
Are you interested in converting from curtain wall to solid insulated sidewalls?		0	Broiler houses are typically curtain wall sided houses and have a big opportunity to move to solid insulated side walls
Is the framed portion of your sidewalls insulated?		0	
If you have curtain sidewalls, are the curtains insulated?		0	Curtain sidewalls can have a 3-ply insulated material, instead of just one layer of plastic, saving on heating costs
Do you have attic inlets in your house(s)?		0	
Do you have ceiling stir fans (used for heating)?		0	This pushes hot air back down into house saving heating costs
Are your tunnel ventilation fans older than 10 years?		0	
Has the house(s) been recently sealed from air leaks?		0	This typically involves spray foaming in all cracks/leaks, etc. to save on heating costs
Do you use radiant heaters in your house(s)?		0	If they are using forced hot air and pancake broods there is the opportunity to move to radiant heating
Do you use incandescent lights?		0	
Do you have insulated tunnel inlet doors?		0	
Are your fans thermostatically controlled?		0	
Total		0	
Energy Audit Recommended? (if greater or equal to 2)		NO	

This Audit Ranking Guide was developed by EnSave for its use in determining the potential value of conducting an energy audit. Not to be used without EnSave's permission.

EnSave

Audit Ranking Guide

65 Millet Street, Richmond, VT 05477
802-434-3792

POULTRY HOUSING- Layers or Breeders

Are you currently permitted as a Confined Animal Feedlot? (CAFO) Yes/No If yes, audit is not applicable		
Does your egg storage room have at least 6 inches of batt or loose fill insulation, or 1.5 inches of foam insulation at the ceiling?		0
Are your egg storage room walls insulated?		0
Are you interested in upgrading your egg storage room heating and cooling system?		0
Are your ventilation fans older than 10 years?		0
Would you like us to evaluate an alternate, more efficient, lighting system for you?		0
Total		**0**
Energy Audit Recommended? (if greater or equal to 2)		**NO**

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Audit Ranking Guide

65 Millet Street, Richmond, VT 05477
802-434-3792

SWINE HOUSING- HEATING 2 OR MORE HOUSES

Are you curmetly permitted as a Confined Animal Feedlot? (CAFO) Yes/No If yes, audit is not applicable			
Do your ceilings in the heated buildings have at least 6 inches of batt or loose fill insulation, or 1.5 inches of foam insulation at the ceiling?		0	
Are you interested in converting from curtain wall to solid insulated sidewalls?		0	Broiler houses are typically curtain wall sided houses and have a big opportunity to move to solid insulated side walls
Are the side walls in your heated buildings insulated?		0	
If you have curtain sidewalls in your heated buildings, are the curtains insulated?		0	Curtain sidewalls can have a 3-ply insulated material, instead of just one layer of plastic, saving on heating costs
Do you have ceiling stir fans in your heated buildings (used for heating)?		0	
Are your tunnel ventilation fans older than 10 years?		0	
Do you use heat lamps for your piglets?		0	
Do you use radiant heaters in your heated house(s)?		0	
Do you use incandescent lights?		0	
Are you interested in upgrading to a more efficient boiler or water heater?		0	
Total		0	
Energy Audit Recommended? (if greater or equal to 2)	NO		

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Audit Ranking Guide

65 Millet Street, Richmond, VT 05477
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DAIRY MILKING AND COOLING

Are you currnetly permitted as a Confined Animal Feedlot? (CAFO) Yes/No If yes, audit is not applicable			
Do you have a vacuum pump motor variable speed drive?		0	Allows for variable speed control on the milk vacuum pump motor, saving energy when less than maximum vacuum is needed - this is not possible on ANY electric motor w/out the addition of a variable control system
Do you use a well water pre-cooler?		0	Uses heat exchanger to pass milk on one side of plates and well water on other, pre cooling milk prior to milk cooling system coming on, w/out MTPVSD, can get milk to w/in 12 degrees of well water temp
Do you have a milk transfer pump variable speed drive?		0	Maximizes heat exchange of pre-cooler by slowing milk flow from harvest system down to a constant rate, and can get milk to w/in 4 degrees of well water temp
Does your milk cooling system use Scroll Compressors?		0	A more efficient type of refrigeration compressor in comparison to a Reciprocating Compressor and can be at least 15-25% more efficient
Are you using any incandescent lights, standard metal halide lamps, mecury vapor lamps, halogen lamps, or older T12 fluorescent fixtures?		0	
Do you use a Compressor Heat Recovery system, also known as FreHeater?		0	Gathers waste heat off milk cooling compressors and then preheats the water going to the water heater to 110 degrees, thus saving on water heater energy costs - electrical, propane, heating oil or natural gas
Are some of your circulation fans older than 10 years?		0	
Are there any large motors on the farm that are old and run for more than 6 hours a day		0	
Total		**0**	
Energy Audit Recommended? (if greater than or equal to 2)	**NO**		

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EnSave

Audit Ranking Guide

65 Millet Street, Richmond, VT 05477
802-434-3792

Feedlots and Beef

Are you currently permitted as a Confined Animal Feedlot? (CAFO) Yes/No If yes, audit is not applicable			
Are you using any incandescent lights, standard metal halide lamps, mercury vapor lamps, halogen lamps, or older T12 fluorescent fixtures?		0	
Do you have any heated stock waterers?		0	Has the potential to go to a low energy or energy free stock waterers
Are some of your circulation or exhaust fans older than 10 years?		0	
Are there any large motors on the farm that are old and run for more than 6 hours a day		0	
Do you use forced hot air for space heating?		0	Has the potential to go to radiant heating
Total		0	
Energy Audit Recommended? (if greater than or equal to 2)		NO	

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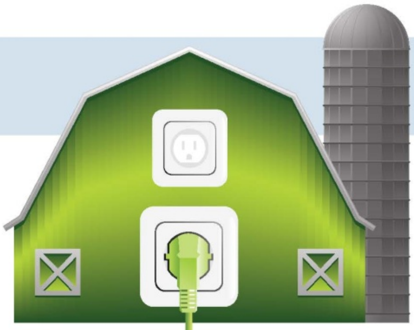
Not to be used without EnSave's permission.

Appendix I

MAESTRO Program Flyer

GET PLUGGED INTO...

MAESTRO



Missouri Agricultural Energy Saving Team - A Revolutionary Opportunity

MAESTRO is a program funded by the U.S. Department of Energy and operated by the Missouri Department of Agriculture, University of Missouri and EnSave, Inc. The program offers farm Energy Management Plans, Technical Assistance and Home Energy Audits.

MAESTRO looks at ways to save energy on the whole farm including the farm residence through the installation of energy efficient equipment.

> **"The audit helped me realize the potential of energy efficient equipment. I now look at my operation completely different."**
>
> *Steve Shehadey, Dairy Farmer*

Program Highlights:

- **Energy Management Plans** – a $1,500 value for only $250, FREE if you install the recommended equipment
- **Free Technical Assistance**
- **Home energy audit** – a $500 value for only $125, FREE if you install the recommended equipment
- **Incentives up to 75% of the total project cost, not to exceed $5,000**
- **Loan buy down to 3%** - up to $50,000, and
- **75% loan guarantee for loans up to $50,000**

To receive incentives, projects must have 15% energy savings or greater.

For assistance call the MAESTRO TEAM at (800) 732-1399
MoAgEnergySavings.org

SAVING ENERGY. STRENGTHENING AGRICULTURE.

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EnSave

Energy saving technologies must be installed no later than November 30, 2012.

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