Human Machine Interface Programming and Testing

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Final Report Abstract:

Human Machine Interface (HMI) Programming and Testing is about creating graphical displays to mimic mission critical ground control systems in order to provide NASA engineers with the ability to monitor the health management of these systems in real time. The Health Management System (HMS) is an online interactive human machine interface system that monitors all Kennedy Ground Control Subsystem (KGCS) hardware in the field. The Health Management System is essential to NASA engineers because it allows remote control and monitoring of the health management systems of all the Programmable Logic Controllers (PLC) and associated field devices. KGCS will have equipment installed at the launch pad, Vehicle Assembly Building, Mobile Launcher, as well as the Multi-Purpose Processing Facility. I am designing graphical displays to monitor and control new modules that will be integrated into the HMS. The design of the display screen will closely mimic the appearance and functionality of the actual modules. There are many different field devices used to monitor health management and each device has its own unique set of health management related data, therefore each display must also have its own unique way to display this data. Once the displays are created, the RSLogix5000 application is used to write software that maps all the required data read from the hardware to the graphical display. Once this data is mapped to its corresponding display item, the graphical display and hardware device will be connected through the same network in order to test all possible scenarios and types of data the graphical display was designed to receive. Test Procedures will be written to thoroughly test out the displays and ensure that they are working correctly before being deployed to the field. Additionally, the Kennedy Ground Controls Subsystem's user manual will be updated to explain to the NASA engineers how to use the new module displays.

I. Introduction

The Kennedy Ground Control Subsystem (KGCS) is a Programmable Logic Controller (PLC) based industrial control system tasked with the responsibility of developing command and control capabilities for specialized equipment in support of the Ground Systems Development Operations program (GSDO). The GSDO Program's mission is to prepare the Kennedy Space Center (KSC) to process and launch the next generation of rockets and spacecraft in support of NASA's exploration objectives by developing the necessary ground systems, infrastructure and operational approaches. To support this mission, KGCS will need to have equipment installed at the launch pad, Vehicle Assembly Building, Mobile launcher, and the Multi-Purpose Processing Facility.

In addition to the command and control function, the KGCS also provides an advisory system for its equipment. The KGCS Health Management System (HMS) is a collection of Human Machine Interfaces (HMI), or displays, that allow KGCS engineers to monitor the health and status of all KGCS equipment deployed in the field from a centralized location. The HMS increases the KGCS engineer's operational awareness capabilities by providing real time feedback on the health and status of all equipment used in KGCS. This knowledge becomes especially important during vehicle launch operations to aid in troubleshooting and anomaly detection. In order to ensure that the data displayed by these HMIs is accurate, each HMI must be thoroughly tested and certified for use in the field before it can be deployed. Once deployed to the field, all KGCS equipment implementing that display must be retested to find any inconsistencies in the system.

The process involved in creating these HMIs starts with the identification of a new hardware device, or module, to be used in the field. For this project, HMIs were developed for the following hardware devices:

- Redundant Ethernet/IP to Foundation Field Bus (EN2FFR) Linking Device Module.
- DeviceNet Module.
- 16 point Normally Open Individually Isolated Relay Contact Output Module (OW16I).

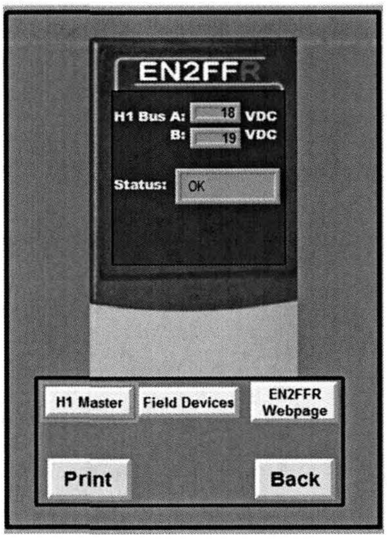
These devices are scheduled to be installed by KGCS as part of the Multi-Purpose Processing Facility installation. The HMIs for these devices were created using the FactoryTalk View Studio application and were designed to closely mimic the appearance and functionality of the actual hardware. Once the graphical display was created, health and status routines were created to populate the data required by the HMIs with values from the hardware. These health and status routines are created using a program called RSLogix5000 and are installed on the actual PLC processor. When these routines execute, they gather the required information into constructs referred to as "tags". These tags are then communicated to the HMI Server via an EtherNet/IP network connection where they are mapped to their appropriate spot on the graphical display. After communication of all system components is established, thorough testing is performed to ensure the HMI is performing all its required design specifications. The final step of this process is to draft user manual and test procedure documentation that accounts for all possible scenarios that NASA engineers may encounter while using this device in the field.

II. Details

The first step to creating a new HMI is to understand the complete functionality of that device. For instance, does the device have LED status indicators and if so what are all the possible conditions and states of these indicators. Also, if the device has some form of alphanumeric display it is important to know every possible condition this screen can display and when it displays them. This information is not always made readily available, this part of the design phase often becomes tedious because the designer must search through various user manuals and documentation to find any relatable information that can be used. It often becomes necessary to call the device manufacturer and speak with the interoperability engineers for that specific device in order to discover specialized details about its operability. Once all pertinent information about the device is gathered a design is pieced together.

After the design of the graphical display is finished the hardware device is placed in a PLC chassis where is it connected via backplane to communication modules and or a PLC. At this point a network is established through Ethernet/IP or Control Net to connect RSLogix5000 and FactoryTalk View software applications to PLC chassis where the hardware device is located. Once all the system components are communicating properly it becomes time to start the system test procedures. The test procedures are not just important to ensure the operability of the hardware but also to help develop how the graphical display will be designed. Through the use of RSLogix5000 the user can simulate specific conditions by writing software to make the hardware device think some error has occurred or likewise some expected action has taken place. Doing this is very useful because it allows us to see exactly how the device responds to these different conditions. It is important to test every possible condition that would make the device act abnormally as well as normally. Once it is realized how the device will react to any possible condition that may influence its operability and or physical characteristics the graphical display can be likewise programmed to mimic the exact functionality of the device. By simulating the same conditions in FactoryTalk View via RSLogix5000 the graphical display is designed to change states just as the hardware device would change in response to the simulated condition.

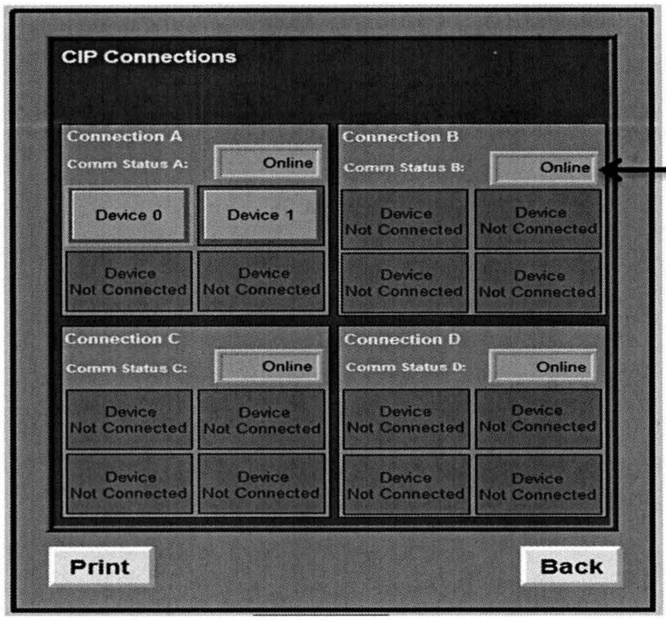
The EN2FF linking device provides a gateway between Ethernet/IP and a single segment Foundation Fieldbus H1 layer. It can support up to 16 devices and is configurable through the RSLogix5000 software application. Multiple levels of media redundancy are supported, including ring, split, and redundant trunk, plus options for H1 media, redundant linking devices, redundant controllers, and ControlNet. In order to develop the HMI for the EN2FFR it was first connected to a power bus then linked to the PLC network via Ethernet/IP and ControlNet modules. The EN2FFR was then physically linked to temperature sensors with manipulation capabilities supplied by decade resistors. Test procedures were then introduced to assess the boundaries of the health management capabilities of the EN2FFR. The reason being to realize what types of health management intelligence could be extracted from the module. After the graphical design was complete, it was linked with the EN2FFR hardware module through FactoryTalk View and RSLogix5000 software applications and tested to ensure that when a health management oriented condition changed on the hardware module it likewise changed the same characteristics on the EN2FFR graphical display. While developing health and status routines for this device I was not able to retrieve certain health information important to the health management of the device. After contacting the interoperability engineer for the EN2FFR it was realized that it was not possible to compel this certain health data out of the EN2FFR. This is often the case when dealing with complex hardware systems and served as a good learning aid in uncovering the boundaries of hardware systems. The following diagrams are screenshots of the EN2FFR display used when creating the user manual for this device.



EN2FFR

H1 Bus A: 18 VDC
B: 19 VDC

Status: OK



CIP Connections

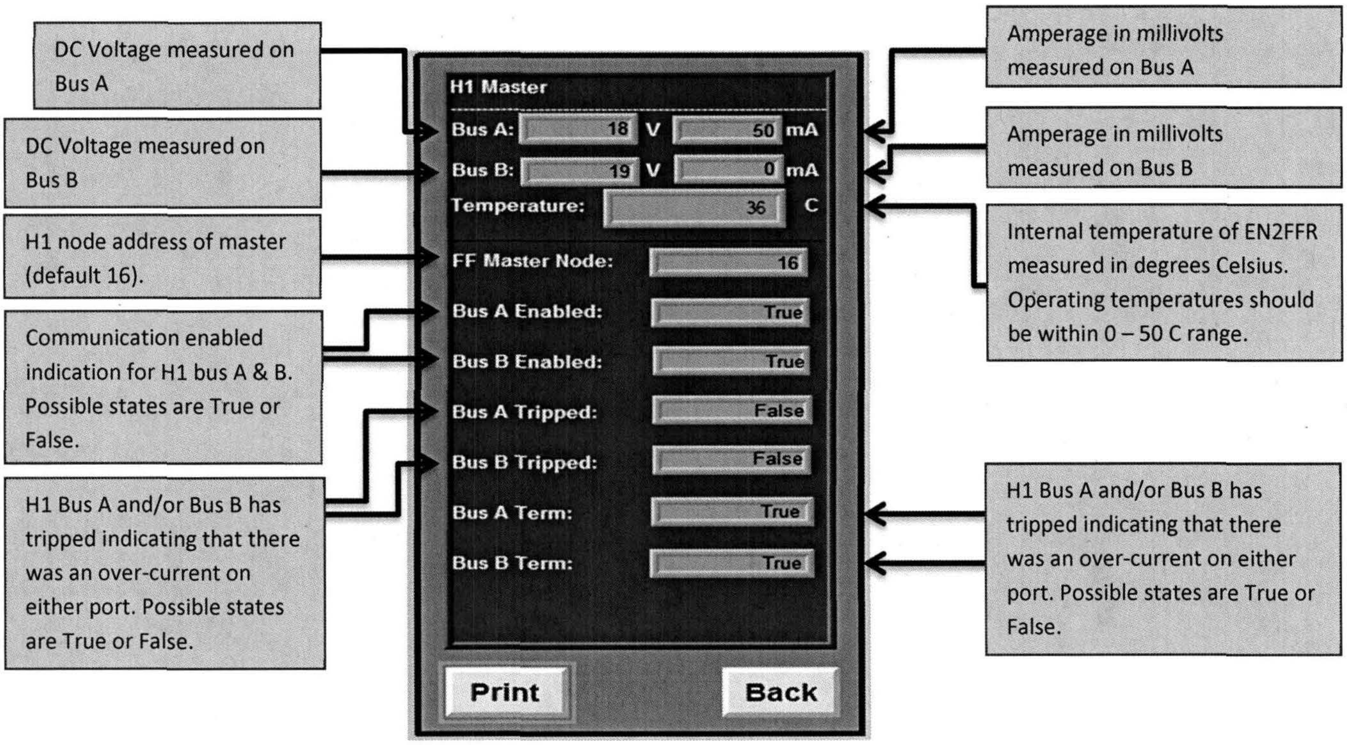
Connection A
Comm Status A: Online

Connection B
Comm Status B: Online

Connection C
Comm Status C: Online

Connection D
Comm Status D: Online

Display of communication status associated with each CIP connection. Possible states are Online & Offline.



H1 Master

Bus A: 18 V 50 mA

Bus B: 19 V 0 mA

Temperature: 36 C

FF Master Node: 16

Bus A Enabled: True

Bus B Enabled: True

Bus A Tripped: False

Bus B Tripped: False

Bus A Term: True

Bus B Term: True

DC Voltage measured on Bus A

DC Voltage measured on Bus B

H1 node address of master (default 16).

Communication enabled indication for H1 bus A & B. Possible states are True or False.

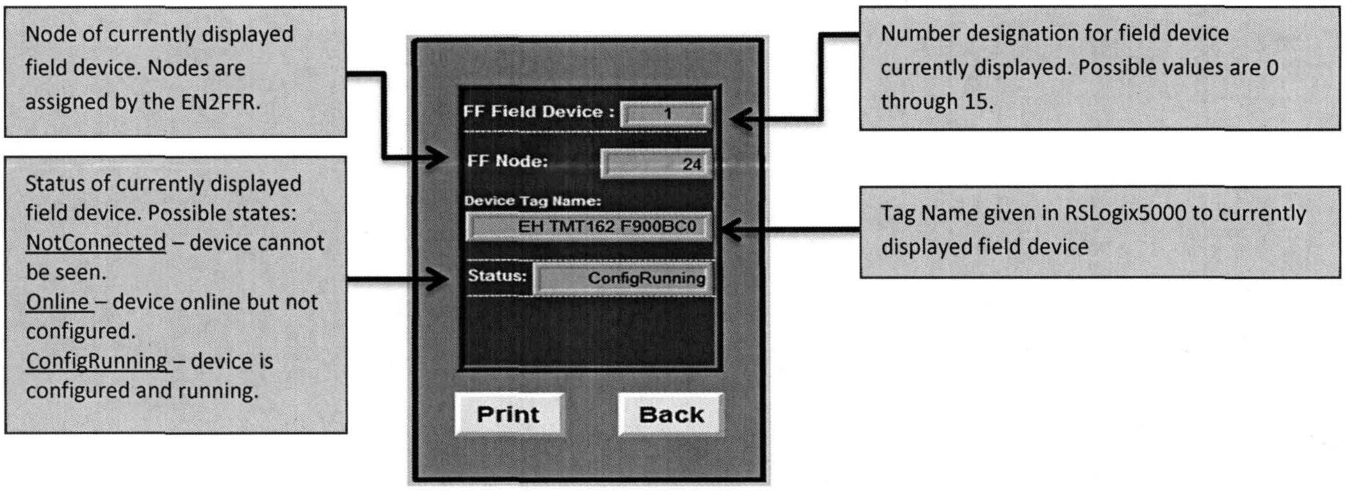
H1 Bus A and/or Bus B has tripped indicating that there was an over-current on either port. Possible states are True or False.

Amperage in millivolts measured on Bus A

Amperage in millivolts measured on Bus B

Internal temperature of EN2FFR measured in degrees Celsius. Operating temperatures should be within 0 – 50 C range.

H1 Bus A and/or Bus B has tripped indicating that there was an over-current on either port. Possible states are True or False.



FF Field Device : 1

FF Node: 24

Device Tag Name: EH TMT162 F900BC0

Status: ConfigRunning

Node of currently displayed field device. Nodes are assigned by the EN2FFR.

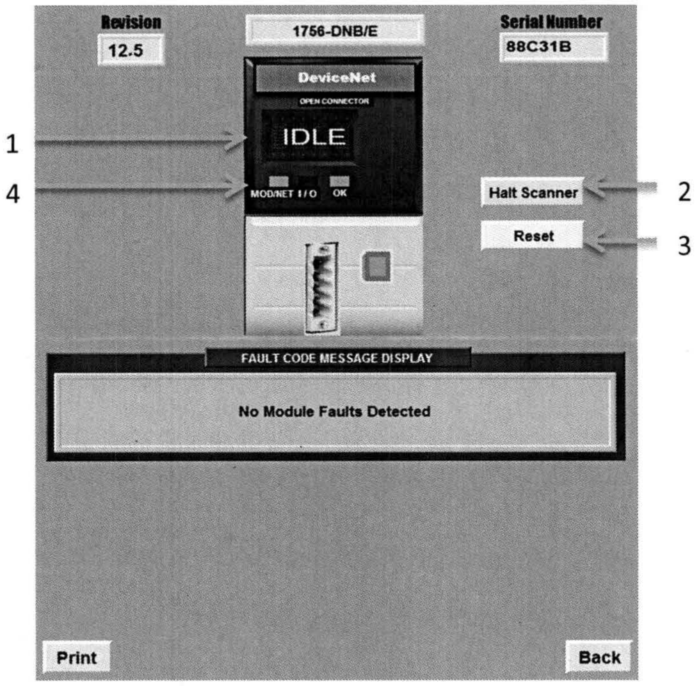
Status of currently displayed field device. Possible states:
NotConnected – device cannot be seen.
Online – device online but not configured.
ConfigRunning – device is configured and running.

Number designation for field device currently displayed. Possible values are 0 through 15.

Tag Name given in RSLogix5000 to currently displayed field device

The functionality of these displays included the design and programming of buttons to allow the user to navigate from the EN2FFR home screen to all subsequent EN2FFR screens to view any associated health or status information.

The DeviceNet Network provides open, device-level control and information networking for simple industrial devices. It supports communication between sensors and actuators and higher-level devices such as programmable controllers and computers. With power and signal in a single cable, it offers simple and cost-effective wiring options. The DeviceNet module was first placed into a Remote Input /Output chassis (RIO) to provide communication capabilities with the PLC network. It was then physically linked to two magnetic Halifax switches in order to test communication and control of devices on the DeviceNet network. While installing the hardware for the DeviceNet module it was realized that there was a communications error between the module and magnetic switches it was linked to. By troubleshooting the power supplies it was discovered that the DeviceNet power tap bus had a blown fuse. This was discovered by using a digital multi-meter to check for voltage on the load side of the power tap bus, after detecting no voltage was being delivered from the bus a check on all fuses associated with power tap bus lead to the discovery of a blown fuse. Once this fuse was replaced the system worked perfectly and testing was resumed. The health management testing procedures were virtually the same as the EN2FFR with the intent of figuring out all possible device health information that could be extracted from the DeviceNet module. One major difference discovered after closer review of the user manual for this module was that more detailed health information for this device was accessible through Common Industrial Protocol (CIP) messaging. By developing the CIP messages through ladder logic programming language via the RSLogix5000 application these messages where sent to the DeviceNet module requesting specific health information. Once this information was retrieved it was stored in a program tag where it could be mapped to its appropriate location on the DeviceNet module. The following diagrams are screenshots of the DeviceNet display used when creating the user manual for this device.



Revision: 12.5

1756-DNB/E

Serial Number: 88C31B

FAULT CODE MESSAGE DISPLAY

No Module Faults Detected

1.) The DeviceNet status display notifies the user:

- What node address the DeviceNet module is currently on.
    - A#00, A#01...A#63.
- The Current status of the module.
    - Idle, Run, Network Disabled, Fault, Test...etc.

2.) Halt Scanner operation allows user to halt all operations on DeviceNet module.

- If Halt Scanner bit is set, user must physically cycle power to restart module.

3.) Reset operation resets all bits to 0 to resume operation.

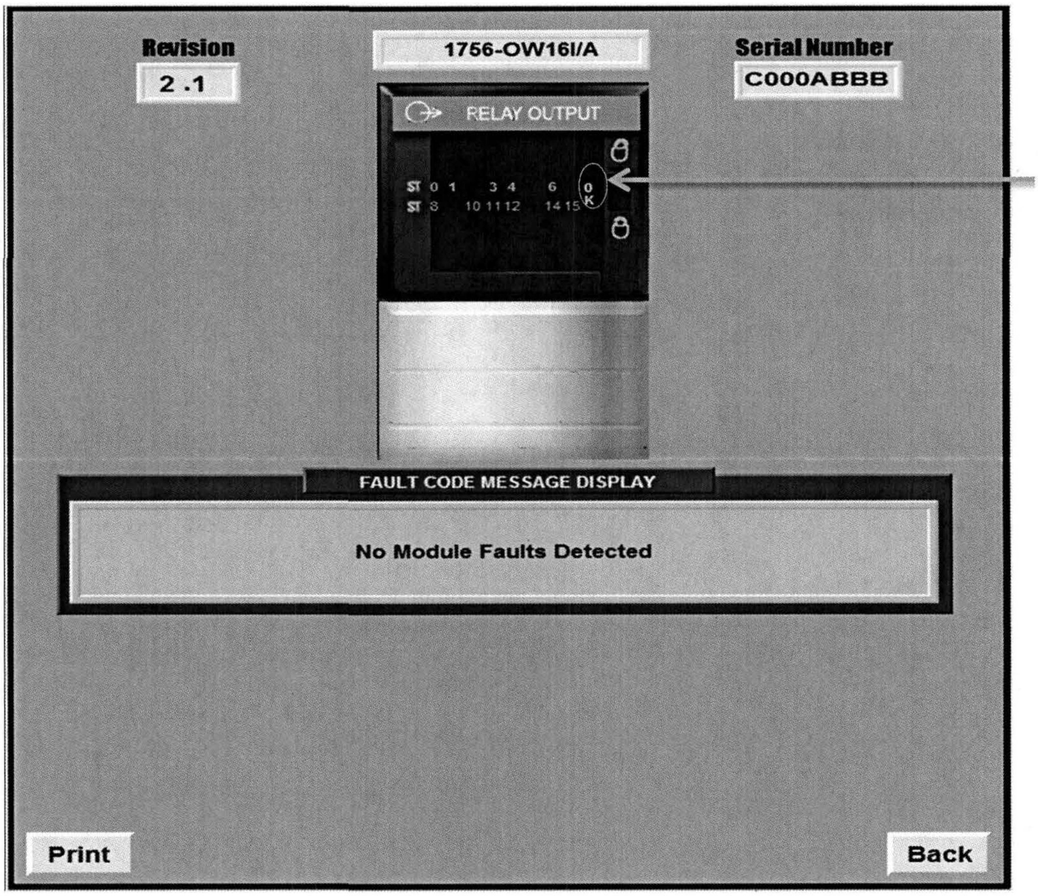
4.) The following table outlines the indicator condition with its corresponding status and explains what each condition means. There are three status indicators on the DeviceNet Module:

- Module/Network (MOD/NET) Status Indicator - This bi-color (green/red) status indicator provides device and communication status.
- I/O Status Indicator - This bi-color (green/red) status indicator indicates the status of the DeviceNet scanner module's I/O scanning state.
- OK Status Indicator - This bi-color (green/red) status indicator indicates whether the device has power and is operating properly.

Indicator	State	Description
Module/ Network (MOD/NET)	Off	Device is not powered/not online.
	Green	Device is operating in a normal condition and is online with connections established.
	Flashing Green (Not displayed on HMI)	Device is operational AND online and not connected or device online and device needs commissioning. The device is operating in a normal condition and is online with no connections established.
	Flashing Red	Minor fault and/or connection time-out - *recoverable fault and/or one or more* I/O connections are in the timed-out state.
	Red (Not displayed on HMI)	Critical fault or critical link failure - device has an unrecoverable fault and may need to be replaced.
I/O	Off	Scanner is not online. Check network power
	Flashing Green	Scanner is in RUN mode, outputs are under control, and inputs are being consumed.
	Green	Scanner is in IDLE mode, outputs are not under control, and inputs are being consumed.
OK	Off	No power applied to device. Apply chassis power. Verify module is completely inserted into chassis and backplane.
	Flashing Green (Not displayed on HMI)	The device is operating correctly; however, no controller is controlling it. Verify that the 1756-DNB scanner module is properly configured in the controller's I/O configuration
	Green	Device is operating normally. The 1756-DNB scanner module has at least one connection to it from a controller.
	Red	Device has an unrecoverable fault; repair or replace it, or Device is in self-test during power-up.

The functionality of the DeviceNet display included the design and programming of multiple multistate indicators to bring visual significance to the LED indicators. The data retrieved from CIP messaging was mapped to the Fault Code Message portion of the display to notify the user if any internal errors occurred in the module and if so what are the courses of action to correct those errors.

The OW16I Relay Contact Output module is an internal mechanical device with a normally open 16 point contact. The OW16I was connected to the PLC network utilizing the same configuration as DeviceNet. For testing procedures it was not needed to connect the OW16I to any external devices because all health associated data from the OW16I was accessible through CIP messaging. Because the DeviceNet module and OW16I module were both manufactured by Allen Bradley the CIP messaging instructions used for the DeviceNet module were reusable for the OW16I module. The OW16I has 16 points of contact therefore a visibility function was coded into the design to allow the user to see which contacts were active at any given time. Also, a multistate visibility function was used for the "OK" module status indicator to notify the user if the modules status was good or poor. The following diagrams are screenshots of the OW16I display used when creating the user manual for this device.



Revision 2.1

1756-OW16I/A

Serial Number C000ABBB

FAULT CODE MESSAGE DISPLAY

No Module Faults Detected

Module Status Indication

By viewing the display the user can realize which output contacts are active and that the device status is currently good. The data retrieved from CIP messaging was mapped to the Fault Code Message portion of the display to notify the user if any internal errors occurred in the module and if so what are the courses of action to correct those errors.

Once all testing and design procedures have been completed a user manual and test procedure for each hardware device has to be documented to address all possibilities NASA engineers may encounter while using this device in the field. The user manual must be very thorough detailing what the hardware device does and what every physical characteristic of the device pertains to internally. If any piece of the device can visually change states, the possible state changes and what those changes mean must also be explained. All information is organized professionally through graphical representations and detailed explanations. After the user manual is finished test procedures for every graphical display associated with the hardware device must be documented. The test procedures provide a system of checks that allow the user to ensure that the changes viewed on the hardware device match the corresponding changes viewed on the display. All data sent from the system and received from field devices that can be viewed on the graphical displays must also be annotated.

III. Conclusion

This internship has been an incredible learning experience, especially at the system level. During this project I have designed and built graphical displays using software and interfaced these graphical displays with the actual hardware they are designed to monitor and control through the development of code in multiple software environments. Then tested all possible scenarios on the hardware to make sure the graphical design and hardware operations were identical. The system level experience I have gained is invaluable to my understanding of how an entire system is designed, tested and ultimately works together to perform complex operations. This experience will without a doubt prove useful in upcoming senor project and future job positions.