VS-OMNI Diagnostics Firmware

ELECOMP Capstone Design Project 2023-2024

Sponsoring Company:

Hayward Industries, Inc.
61 Whitecap Dr.
N. Kingstown, RI 02853
http://www.hayward.com

Company Overview:

For nearly 100 years, Hayward has built industry-leading equipment, filters, and pumps. Today we are at the forefront of innovation for pool and outdoor living technology and internet-connected homes.

We offer a full line of energy-efficient and sustainable residential and commercial pool equipment including pumps, filters, heaters, cleaners, sanitizers, LED lighting, and water features—all of which are digitally connected through Hayward's intuitive IoT-enabled SmartPad™.

Hayward is also the leading manufacturer of industrial thermoplastic flow control valves. And all of our pumps have secured EnergyStar certification, meaning we can save pool owners money on their energy bills.

We are the brand of choice for both new pool builds as well as the aftermarket and help commercial and residential pool owners create their own water experience through convenient solutions that improve ambiance, efficiency, and comfort.

Our global headquarters is in Charlotte, North Carolina, and we have operations across the United States, Australia, Canada, China, France and Spain. We are publicly traded on the New York Stock Exchange under the ticker HAYW.

Technical Director:

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Test, Manufacturing and Automation Eng Mgr.
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BSEE 1992 University of RI
MBA 2020 University of RI

Project Motivation:

Hayward Industries builds, tests, and programs a commercially available pool controller circuit board for our VS-OMNI® line of pool automation equipment. This circuit board is a fully functioning computer with DRAM, NOR-FLASH, EEPROM, LCD controller, Ethernet, USB, and other hardware. The firmware contains a bootloader, real time OS, and custom applications.

During the circuit board assembly process, the pcba (printed circuit board assembly) is tested to make sure all components are within specification and defects such as solder shorts or opens are detected. The testing process includes downloading the latest firmware revision to the NOR-FLASH memory on the pcba.

Upon successful downloading of firmware, the VS-OMNI controller is power cycled, allowing the firmware to execute, where-in the OS boots up and the VS-OMNI application is executed. The downloading of firmware and the boot process can take as long as 4 minutes to complete.

Occasionally, the OS fails to boot and the pcba must then be sent to our diagnostics and repair department for determination of failure. Due to the high density of components and the use of BGA chips, it becomes extremely difficult and nearly impossible to verify all electrical connections to each component. Additionally, if the component itself is defective, all electrical connections may be intact, but the component will not function properly.

To improve the speed of testing and aid in the diagnostic and repair process, hayward Industries would like a 'stripped down' version of firmware, providing a specific set of functions, each targeting a specific hardware component or block of components. This firmware needs to be as small as possible, allowing faster downloading. It must, however, provide sufficient information to aid in diagnosing possible hardware defects. Firmware design should prioritize diagnostic information over code size.

The firmware should operate using a simple loop, waiting for a command to arrive via the DEBUG_UART port. When a command is received, the firmware will acknowledge reception and then proceed to execute the command. When execution of command is completed, any requested information is returned, or a 'COMMAND COMPLETE' response is sent.

Anticipated Best Outcome:

The Firmware (FW) functionality should include the following capabilities:

1. Set Digital I/O port direction (Input or Output).
2. Read/Write Digital I/O ports.
3. Set PWM for specific Digital Outputs.
4. Read/Write UART ports.
5. Read/Write SPI port.
6. Read/Write I2C port.
7. Read/Write Internal RAM.
8. Read/Write DRAM.
9. Read/Write NOR Flash.
10. Read/Write EEPROM.
11. Read/Write RTC (Real Time Clock).
12. Read ADC Channels.
13. Read LCD touch (Read ADC Channel may suffice).
14. Configure/Control Power Supplies (VCore,1.8V,3.3V,5V).
15. Read/Write SD Card.
16. Read/Write USB port.
17. Read/Write Ethernet port.
18. other – TBD.

Project Details:

The project will proceed by developing an understanding of each of the PCBA's basic functional blocks including:

- The Arm MCIMX283CVM4B microprocessor and it's configuration registers,
- External components, i.e., RAM, EEPROM, FLASH, DRAM, RTC, etc.,
- How externally components are wired to micro, i.e., SPI, I2C, digital bus, etc.,
- JTAG programming and debug ports,

Failure mode analysis

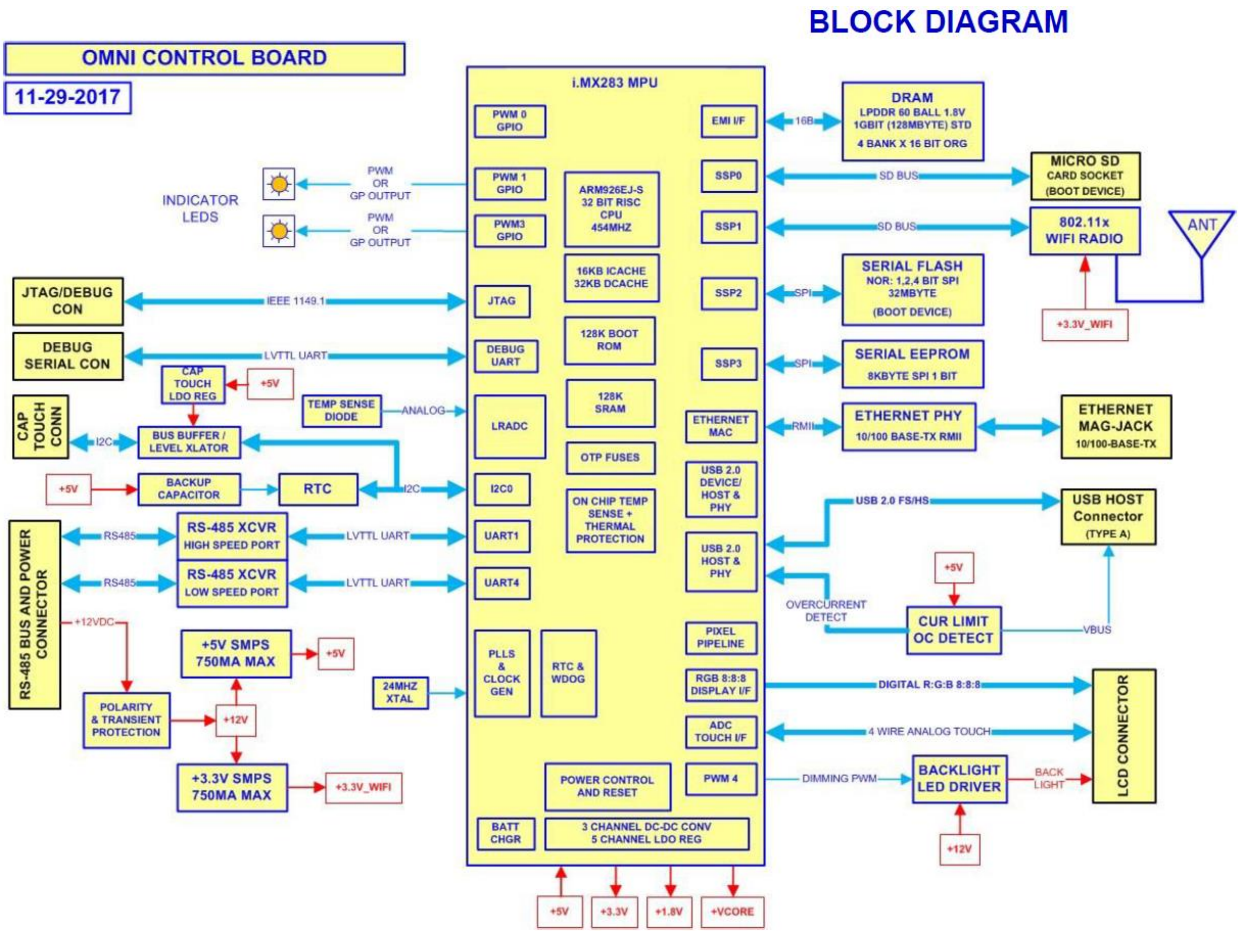
- Overview of failures presently encountered,
- Analysis of possible causes of failures for each hardware component or functional block,

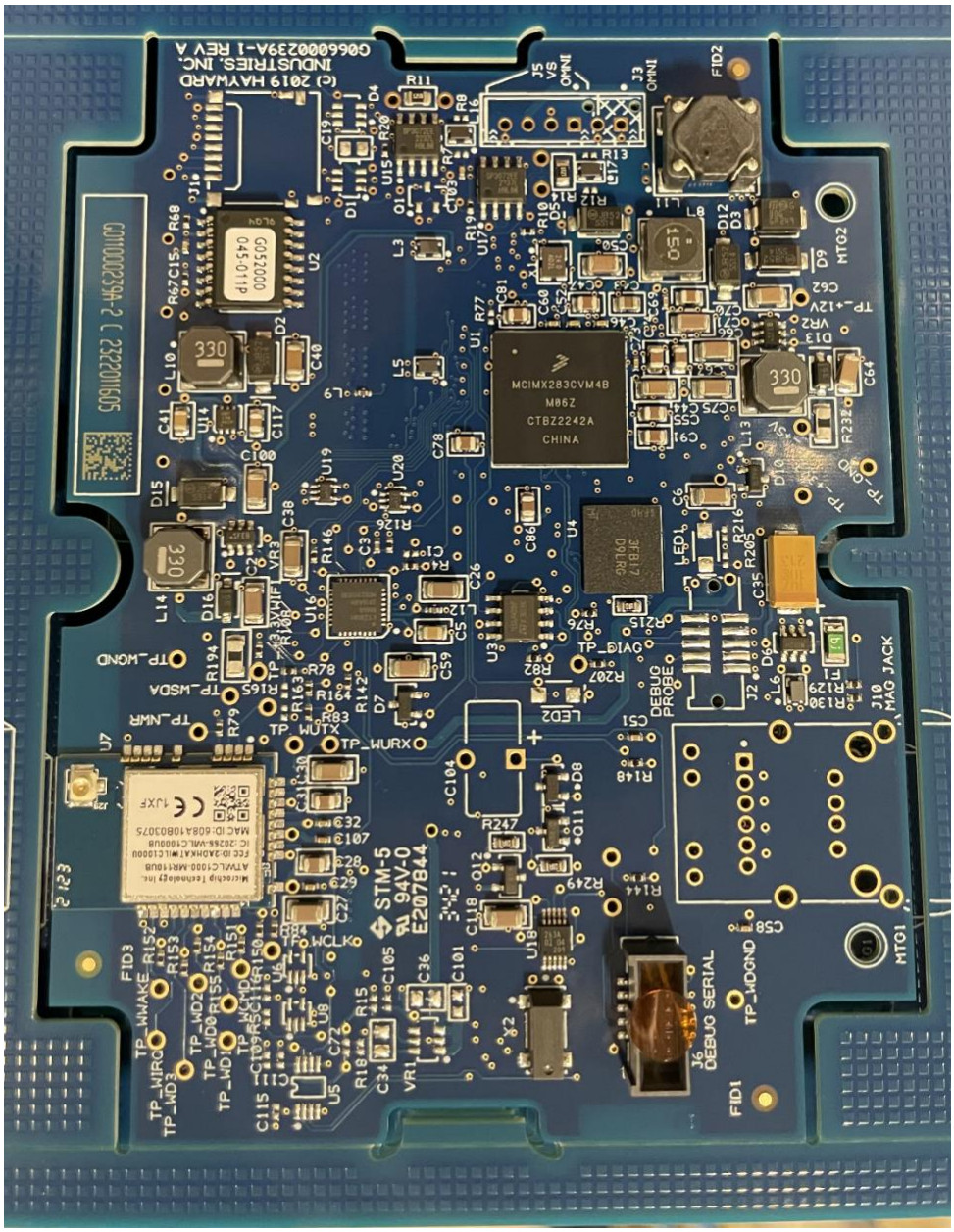
An overview of required software tools will be provided including:

- Compiler and ICSP (In Circuit Serial Programmers) use,
- Use of communications tools such as *putty* or *Docklight*,
- Use of protocol converters for RS232, RS485, I2C, SPI, etc.,

A strategy for FW execution will be developed detailing:

- Setup and initialization requirements,
- Indicators of successful startup,
- Main loop,
- Identification of needed fundamental code blocks,
- Identification and development of test requirements for each hardware component,
- Command specification development,


BLOCK DIAGRAM
OMNI CONTROL BOARD
11-29-2017
i.MX283 MPU
PWM 0 GPIO
PWM 1 GPIO
PWM3 GPIO
JTAG
DEBUG UART
I2C0
UART1
UART4
LRADC
PLLS & CLOCK GEN
24MHZ XTAL
RTC & WDOG
ARM926EJ-S 32 BIT RISC CPU 454MHZ
16KB ICACHE 32KB DCACHE
128K BOOT ROM
128K SRAM
OTP FUSES
ON CHIP TEMP SENSE + THERMAL PROTECTION
POWER CONTROL AND RESET
BATT CHGR
3 CHANNEL DC-DC CONV 5 CHANNEL LDO REG
EMI I/F
SSP0
SSP1
SSP2
SSP3
ETHERNET MAC
USB 2.0 DEVICE/ HOST & PHY
USB 2.0 HOST & PHY
PIXEL PIPELINE
RGB 8:8:8 DISPLAY I/F
ADC TOUCH I/F
PWM 4
+5V
+3.3V
+1.8V
+VCORE
DRAM
LPDDR 60 BALL 1.8V 1GBIT (128MBYTE) STD
4 BANK X 16 BIT ORG
16B
MICRO SD
CARD SOCKET
(BOOT DEVICE)
SD BUS
802.11x
WIFI RADIO
ANT
+3.3V_WIFI
SERIAL FLASH
NOR: 1,2,4 BIT SPI
32MBYTE
(BOOT DEVICE)
SPI
SERIAL EEPROM
8KBYTE SPI 1 BIT
ETHERNET PHY
10/100 BASE-TX RMII
RMII
ETHERNET MAG-JACK
10/100-BASE-TX
USB HOST Connector
(TYPE A)
USB 2.0 FS/HS
OVERCURRENT DETECT
CUR LIMIT OC DETECT
VBUS
DIGITAL R:G:B 8:8:8
LCD CONNECTOR
4 WIRE ANALOG TOUCH
BACKLIGHT LED DRIVER
DIMMING PWM
BACK LIGHT
+12V
INDICATOR LEDS
PWM OR GP OUTPUT
JTAG/DEBUG CON
IEEE 1149.1
DEBUG SERIAL CON
LVTTL UART
CAP TOUCH LDO REG
CAP TOUCH CONN
I2C
BUS BUFFER / LEVEL XLATOR
TEMP SENSE DIODE
ANALOG
BACKUP CAPACITOR
RTC
RS-485 BUS AND POWER CONNECTOR
RS485
RS-485 XCVR HIGH SPEED PORT
RS-485 XCVR LOW SPEED PORT
+12VDC
+5V SMPS 750MA MAX
POLARITY & TRANSIENT PROTECTION
+3.3V SMPS 750MA MAX


MCIMX283CVM4B
M86Z
CTBZ2242A
CHINA
STM-5
94V-0
E207844
DEBUG SERIAL
MAG JACK

Hardware/Electrical Tasks:

- Utilize standard bench test equipment to verify condition of components on circuit board,
- Perform simple circuit analysis and pin characterization of digital and analog circuits,
- Analyze and decode data streams,
- Add and remove components to provide isolation and minimize interference to hardware components being tested,
- Design and build any required interfaces, cabling, etc.,

Firmware/Software/Computer Tasks:

- C, assembler code development for an Arm MCIMX283CVM4B microprocessor,
- Use of compilers and In Circuit Serial Programmers,
- RS232, RS485 communications protocol,
- SPI, I2C communications protocol,
- Use of various PC applications to aid in FW development and testing, this may include developing small utilities to communicate to pcba via RS232 DEBUG_UART.
- Use of 3rd party products such as protocol converters for RS232, SPI, I2C, ethernet, etc.,

Composition of Team:

1 Electrical Engineer & 1 Computer Engineer

Skills Required:

Electrical Engineering Skills Required:

- Reading circuit schematics
- Understanding component specifications using manufacturer's datasheets
- Use of standard bench test equipment such as DMM's, Oscilloscopes, Power Supplies,
- Use of standard electrical tools including soldering/desoldering equipment,
- Ability to develop external electrical circuits to aid in measuring and testing electronic circuits,

Computer Engineering Skills Required:

- C, assembler code development for an Arm MCIMX283CVM4B microprocessor,
- Use of compilers and In Circuit Serial Programmers/Debuggers,
- RS232, RS485 communications protocol,
- SPI, I2C communications protocol,
- Use of various PC applications to aid in FW development and testing, this may include developing small utilities to communicate to pcba via RS232 DEBUG_UART.
- Use of standard bench test equipment such as DMM's, Oscilloscopes, Power Supplies,
- Use of standard electrical tools including soldering/desoldering equipment,
- Ability to develop external electrical circuits to aid in measuring and testing electronic circuits,
- Use of 3rd party products such as protocol converters for RS232, SPI, I2C, ethernet, etc,

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

Test firmware will be utilized by our pcba rework and repair group to aid in determining faulty components. Currently, this process can require many hours of debugging, quite often resulting in replacing one component at a time until root cause of failure is determined. The repair process can also inadvertently damage a circuit board resulting in scrap, costing the company significant amounts of money.

By using test firmware that can target specific hardware components, a more methodical approach to determining root cause of failure can be developed.

Additionally, the test firmware can be incorporated into the pcba testing process. This will provide our automated test systems with a tool to more rapidly, and more thoroughly test the product.

Broader Implications of the Best Outcome on the Company's Industry:

During the last few years, the electronics industry, along with many others, has experienced significant supply chain issues. Difficulty in acquiring the necessary electronic components has resulted in significant loss of revenue for these companies, including many downstream all the way to the end user. Worse, unfortunately, there are actors in the supply chain who fraudulently supply defective or 'pirated' components.

Having the tools available to quickly assess the proper functionality and quality of the products built, results in products getting to the customer faster while reducing the likelihood of creating scrap. Costs can be better maintained, helping to keep prices reasonable.