

ECE 445
Spring 2016
Design Review

Retail Smart Hanger

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Table of Contents

1. Introduction.....	4
1.1 Statement of Purpose.....	4
1.2 Objective	4
1.2.1 Goals and Functions	4
1.2.2 Benefits and Features	4
2. Design.....	5
2.1 Block Diagrams	5
2.1.1 High Level Block Diagram.....	5
2.1.2 Physical Block Diagram	5
2.1.3 Top Level Device Data Flowchart.....	6
2.2 Block Description	6
2.2.1 Charging Station (Power Adapter)	6
2.2.2 Power Circuitry.....	7
2.2.3 Data Collection / Processing.....	9
2.2.4 User Interface (Consumer).....	11
2.2.5 User Interface (Store Employee)	13
2.3 Calculation and Simulation	15
2.3.1 Power Consumption.....	15
2.3.2 Power Circuitry Calculation	16
3. Requirement and Verification	17
3.1 ESP8266 - ESP01 Wi-Fi Module	17
3.2 ATmega328P-PU	18
3.3 2.8" SPI TFT LCD.....	19
3.4 Power Adapter	19
3.5 Lithium Polymer Battery	20
3.6 Power Converter	20
3.7 Tolerance Analysis.....	21
3.8 LabVIEW Front End Application.....	21

4. Cost and Schedule	24
4.1 Cost Analysis	24
4.1.1 Labor	24
4.1.2 Parts	24
4.2 Grand Total	25
4.3 Schedule	25
5. Safety and Ethics.....	26
5.1 Safety Statement	26
5.2 Ethical Concerns	27
6. Appendix.....	28
6.1 Appendix A.....	28
6.2 Appendix B	29
6.3 Appendix C	31
6.4 Appendix D.....	32
7. Reference	37

1. Introduction

1.1 Statement of Purpose

In today's world, fashion trends progress at an incredibly fast rate. With frequent fashion trend changes forces clothing retail stores to purchase new clothing often. With new styles of clothing, seasonal changes, and holiday seasons, it brings big burden on employees to continuously update pricing of clothing. Therefore, there are many instances where price and size labeling of clothing in retail stores are displayed incorrectly, causing confusion and frustration on consumer's part. This forces the employees to spend a substantial amount of time correcting these labels. Hence, this leads to hiring more employees than necessary and causes less interaction between employees and customers.

With that said, our project focuses on developing a digital hanger with a palm-sized LCD to display normal/discounted prices, sizes, clothing compositions, and any other information store owner wishes to display. This product will be capable of updating price remotely and updating all of store pricing with few simple steps for seasonal sales. Furthermore, this prototype will feature a "SNS-like" feature of creating a "like button" to track how many times customers showed interest in the clothing to give store owner/managers an idea which fashion trends to invest in the future. This prototype will require two components. First component is the hanger and the second is the charging station which user can easily charge by simply hanging into the charging port.

1.2 Objectives

1.2.1 Goals and Functions

- Easy to view information pertaining to product
- Ease of changing price on clothing articles
- Increase employee productivity
- Increase sale through tracking fashion trends
- Enhance aesthetics through option of changing color on display
- Develop stand-alone front-end application with GUI for usability

1.2.2 Benefit and Feature

- Display brand name, retail/sale prices
- Display size and information user wishes to put onto the hanger (ex: New Winter Collection)
- Unique mechanical design of charger port for ease of charging
- Rechargeable battery for portability
- Transmit and receive data wirelessly through TCP/IP protocol
- Track and store product statistics
- Reduces amount of paper disposal through paperless system\

2. Design

2.1 Block Diagrams

2.1.1 High Level Block Diagram

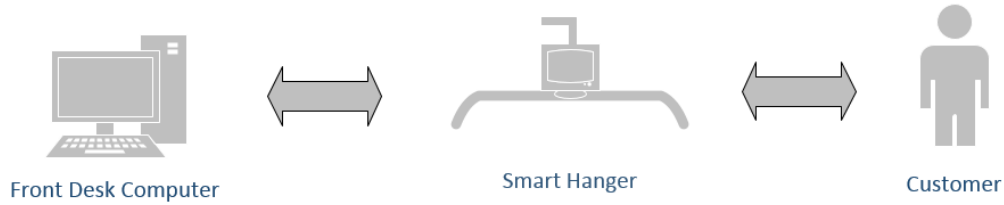


Figure 1.1 Top-Level System Block Diagram

2.1.2 Physical Block Diagram

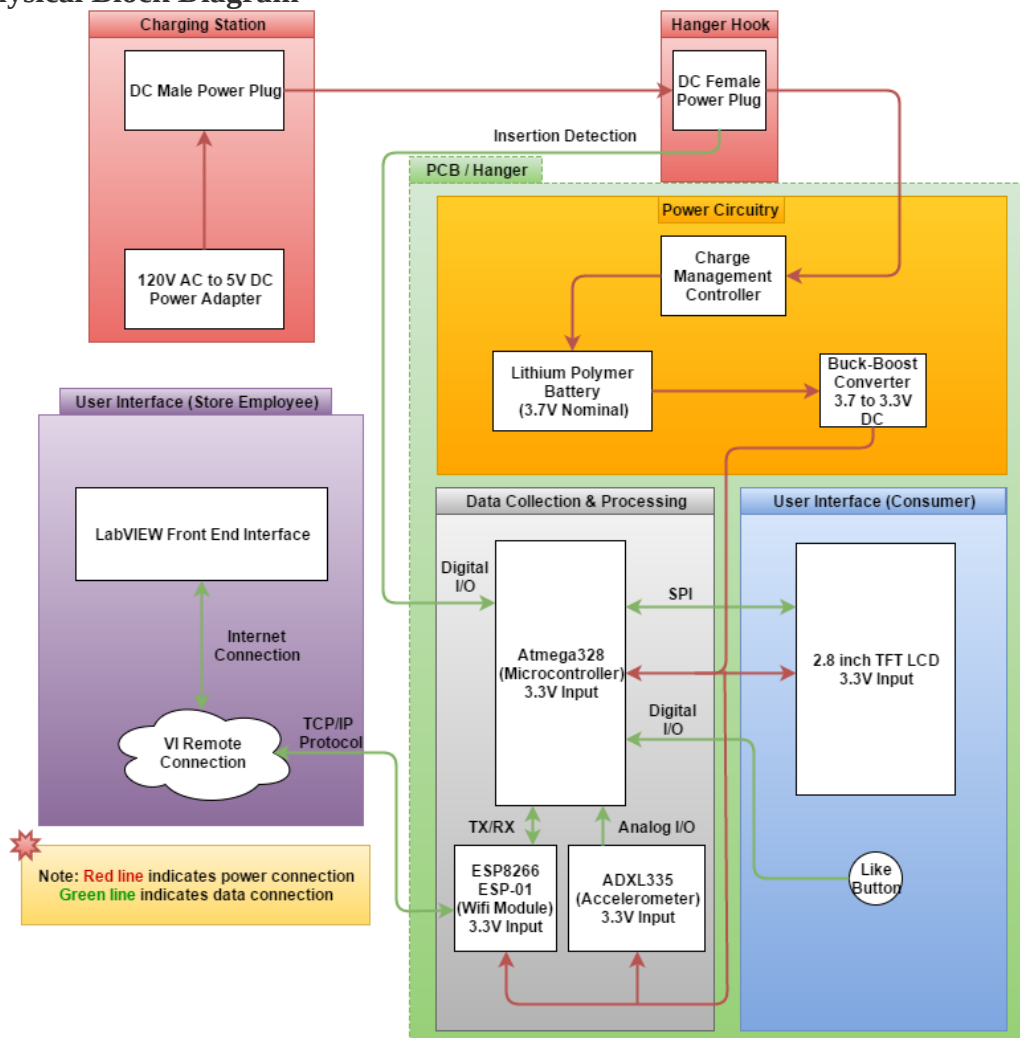


Figure 1.2 Top-Level System Block Diagram

2.1.3 Top Level Device Software Flowchart

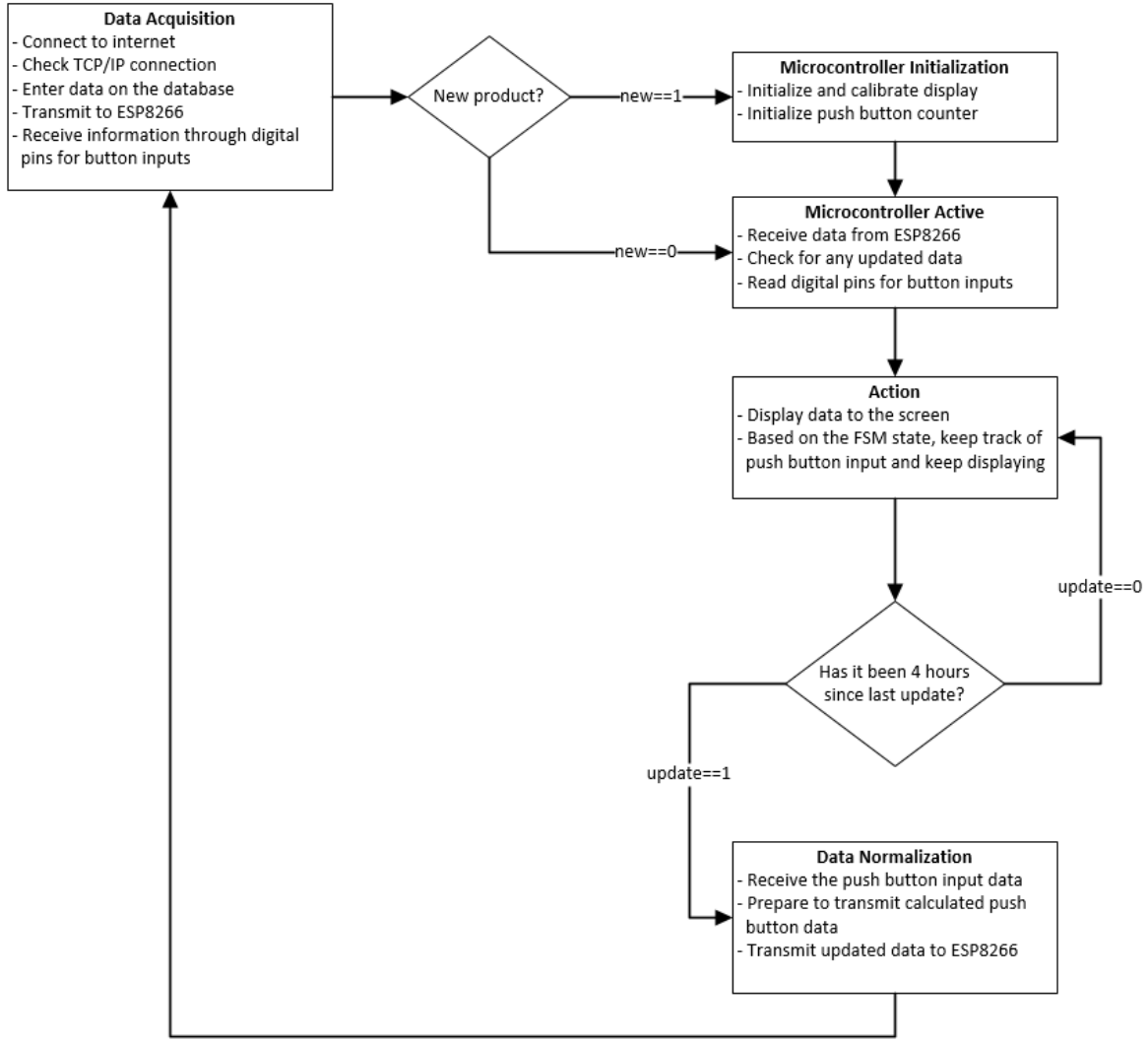


Figure 1.3 Top-Level Device Software Algorithm

2.2 Block Descriptions

2.2.1 Charging Station (Power Adapter)

Input: 120V AC Wall Outlet

Output: 5V DC, 500mA $\pm$ 5% to each male pin

1. Power Adapter

To charge the lithium polymer battery, we need an AC to DC power outlet that steps down 120V AC to 5V DC. For the sake of prototyping, we decided to only implement two DC male pin on the charging station. Since the battery is charged with 500mA, we wanted to ensure that the current rating is more than enough to handle two charging ports. For this reason, we decided to

choose a readily available 5V output with 2A maximum current rating power adapter. If one wishes to implement more charging ports on the charging station, he/she would need to choose the power adapter with enough current rating to satisfy overall power rating requirement. As with the hanging hook, we decided to approach the charging problem with a creative mechanical solution by having the female dc port located on the hanger. This way, user does not need to manually plug in charging cable every time hanger requires charging.

2. 2.5mm DC barrel male/female connector

A key component to this project is making the prototype energy efficient. In order to achieve longevity of device power, we need a system which detects when the hanger is currently on rack. To achieve this with minimal cost and accuracy, we decided to implement power charge detect circuitry by using dc jack insertion detection pin.

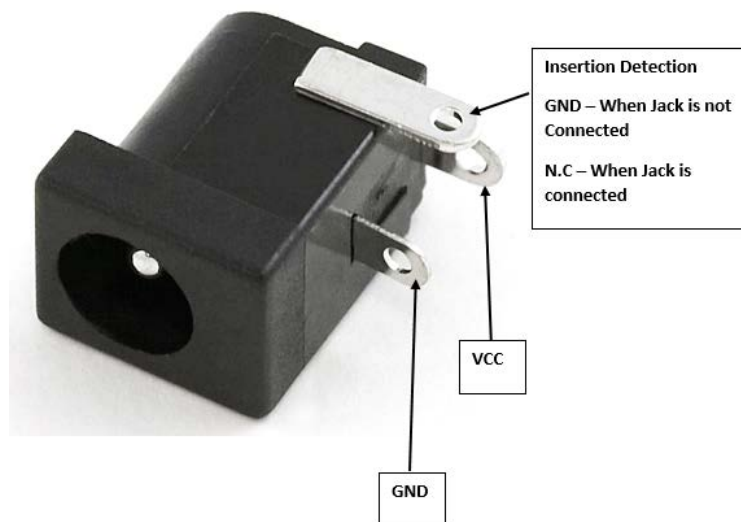


Figure 1.4 Female DC barrel

As shown in figures 1.4, the female DC barrel that is connected to the hanger has a 3rd pin for insertion detection. With this detection pin, we are able to know exactly when the pin is plugged into the port through using a pull up resistor technique. It is also important to note that this pin acts as a switch. As shown in figures 1.5, we see that when the male jack is not connected, the insertion pin shorts to ground, which causes digital I/O to see low voltage value. When the pin is plugged into the port, the insertion pin breaks off from ground, in which the digital I/O sees a high voltage. From software standpoint, we could detect when the digital I/O sees high or low and put device to either sleep or active mode.

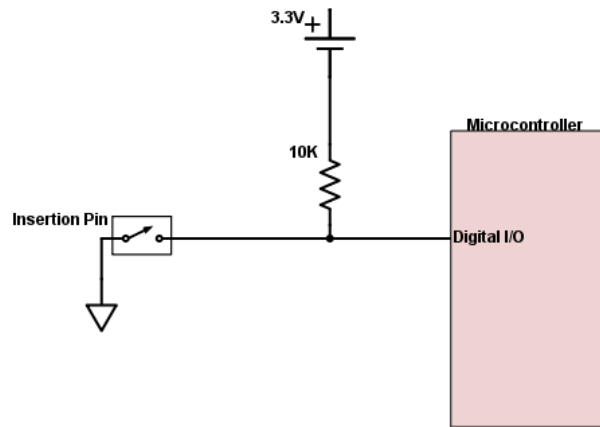


Figure 1.5. Pull Up resistor schematic of insertion detection

2.2.2 Power Circuitry

As for the power circuitry, we need a charge management controller, lithium polymer battery, and buck boost converter to satisfy varying level of input voltages. The SMPS (namely, buck-boost converter) are required to satisfy power requirements for various components in the overall circuit. Detailed power calculation is outlined in the calculation section.

1. Charge Management Controller (MCP73831)

Input: $5V \pm 20\%$, 500uA charge current to IC

Output: $4.2V \pm 0.75\%$, 500mA charge current $\pm 10\%$ to each male pin

To charge a rechargeable battery safely, we need to implement a charge management controller in our power circuitry. To meet our device and battery specification, we chose the MCP73831 as our battery management controller. This management controller is capable of employing constant current voltage and current charging level with four voltage regulation options. We want to use 4.2V as our voltage regulation since our battery charge cut-off voltage is rated at 4.2V. As with charging current, we need to be charging at 500mA, which is the maximum allowable charging current. This is to ensure that charging of battery does not take longer than 5 hours assuming battery is at UVLO voltage level [10].

Another important factor to consider is the Undervoltage Lockout(UVLO). When supply voltage is less than the undervoltage lockout, the charge IC goes into shutdown mode until the supply voltage increases to level above UVLO threshold. This feature is to ensure protection of equipment as well as the battery itself.

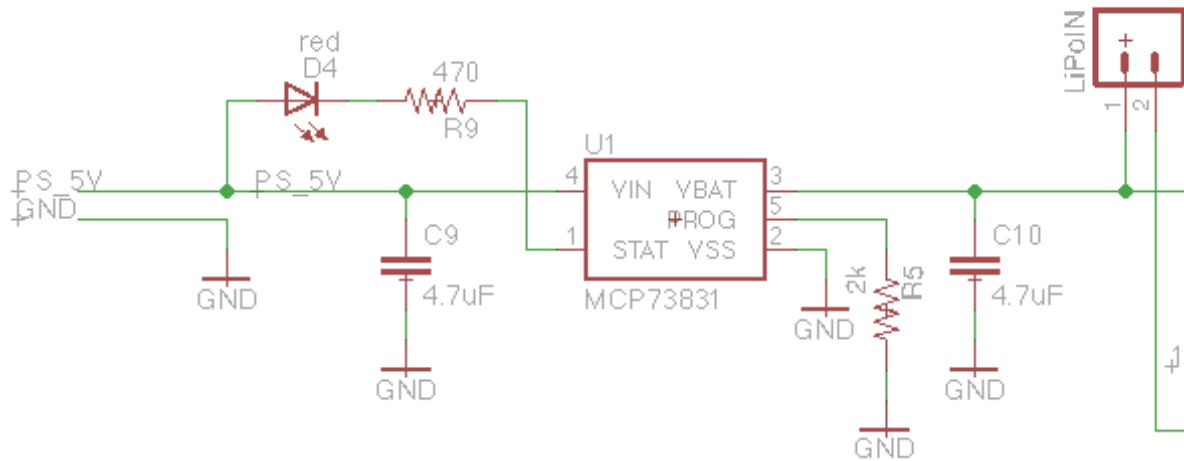


Figure 1. MCP73831 Circuit Schematic

2. Lithium Polymer Battery (2000mAh Unionfortune lithium ion polymer battery)

Power specification: 3.7V Nominal, 4.2V $\pm$.03V - charge cut-off voltage, 2.75V - discharge cut-off voltage, 2.0 CsA - max discharge current, 1.0 CsA – max charge current

We want to ideally have the capability of product lasting for at least 3 hours given all components being turned on. We also need the system to be rechargeable, which brought us to choose a lithium ion polymer battery. Detailed calculation will follow in calculation section. We have previously stated that the battery needs to be charged at a 500mA to match our current consumption. To meet all of the specification required, we chose Unionfortune polymer lithium-ion battery rated at 2000mAh with nominal voltage of 3.7V. The discharge cut-off voltage is 2.75V and the charge cut-off voltage is at 4.2V $\pm$.03V. We are ensured that the voltage level does not fall below 3.2V UVLO stop threshold value as defined by MCP73831. Also, the regulated output voltage is at 4.2V $\pm$ 0.75%, which we can see that all of required specification is met. A minor complication behind the varying voltage level to power devices rated at 3.3V is solved through a use of Buck-Boost converter.

3. Buck-Boost Converter (TPS63031)

Input: 1.2V to 5.5V, 1000mA maximum input current

Output: Fixed 3.3V, 800mA maximum output current

As previously stated, we need to address the varying input voltage to a fixed output voltage of 3.3V. To achieve this problem in an efficient manner, buck-boost converter is the best solution to create a fixed level voltage. First, we need to make sure that all the input current requirement is met as well as max discharge current from the lithium polymer battery. As shown in calculation section, we meet the input current requirement and meet the max discharge current of 2.0 CsA from the lithium polymer battery [8].

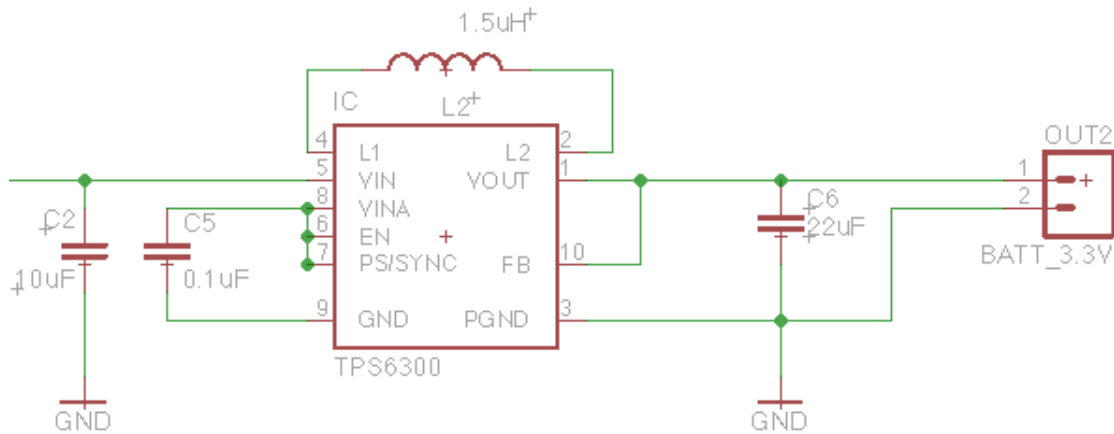


Figure 2. TPS63031 Circuit Schematic

2.2.3 Data Collection/Processing

As shown in the block diagram, the microcontroller and Wi-Fi module will be responsible for connecting front end application to transfer, collect and process data.

1. Microcontroller (ATMega328P-PU)

Input: 3.0-3.3V power input, Wi-Fi data receiver line (RX), data transfer line to display module (MOSI), ‘Like’ buttons data from switch (GPIO8) and Reset button (PC6)

Output: Commands to write new data to display, commands to transmit ‘Like’ button information to Wi-Fi module (TX), data transfer line from display module (MISO), LCD clock line (SCL), LCD select line (SS) and ‘Like’ buttons data to Wi-Fi module (GPIO8)

This unit receives the product information data (retail price, sale price, size, banner etc.) from retail store’s front desk computer through ESP8266 interface (RX and TX pins) wirelessly. The acquired product data will be transmitted to the 2.8 inch TFT SPI LCD display screen by Master Out Slave In (MOSI) pin. Then, display module sends the “Like” button information back to the ATMega328P through Master In Slave Out (MISO) pin. Microcontroller will then send this information back to the store’s front desk computer through ESP8266 module. Detailed data processing models are discussed further in “Wi-Fi Module (ESP8266)” block description.

The ATMega328p microcontroller will be powered by a +3.3V source regulated by a +3.7V battery and integrated with the display, Wi-Fi, crystal oscillator, power supply and ‘Like’ button modules on a PCB. A pint layout summary of these interfaces is shown in Figure 3.

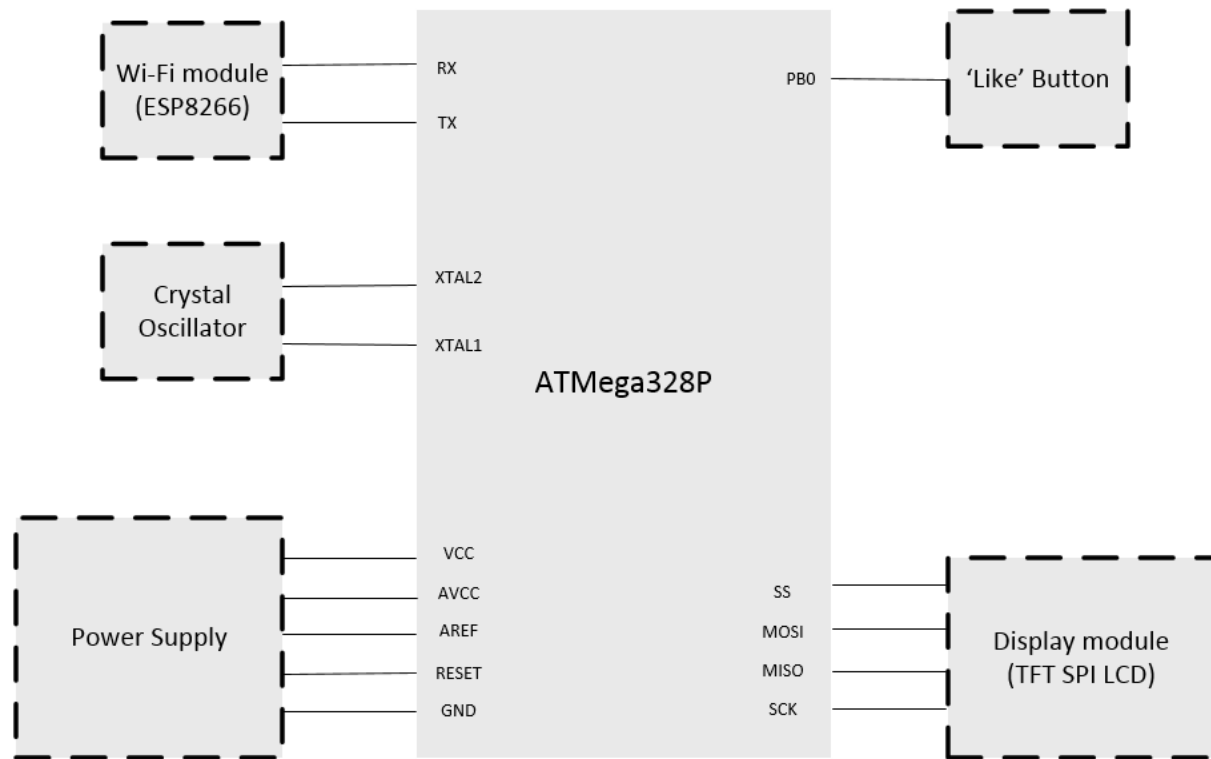


Figure 3. ATmega328p interfaces to other components

Pin	Function	Connection
1	RESET signal, active high	to reset button
2	RX, serial receive	to TX of ESP-8266 module
3	TX, serial receive	to RX of ESP-8266 module
7,20	VCC/AVCC, digital/analog voltage supply	to regulated supply (+5v)
8,22	GND, ground	to ground supply
9	XTAL1, external clock input 1	to oscillator
10	XTAL2, external clock input 2	to oscillator
14	PB0, digital GPIO pin 8	to 'Like' button
16	SS, digital GPIO pin 10	to CS of serial SPI LCD
17	MOSI, digital GPIO pin 11	to SDI of serial SPI LCD
18	MISO, digital GPIO pin 12	to SDO of serial SPI LCD
19	SCK, digital GPIO pin 13	to SCL of serial SPI LCD
21	AREF, analog reference voltage (top of input voltage range)	to regulated supply (+5v)

Table 1. Pin connection for the ATmega328p to other components

2. Wi-Fi Module (ESP8266)

Input: 3.6V maximum, 300mA maximum input current, Rx pin to receive data from ATmega328

Output: Tx pin to send data to ATmega328

Pin	Function	Connection
1	UTXD, Transmit (Data out)	to digital IO pin 2 of ATmega328p
2	CH_PD,	to Vout of buck-boost
3	RST, Reset	to reset of ATmega328p
4	Vcc, Input voltage	to Vout of buck-boost
5	URXD, Receive (Data in)	to digital IO pin 3 of ATmega328p
6	GPI0, General purpose input output	N/A
7	GPI12, General purpose input output	N/A
8	GND,gnd	to ground of buck-boost

Table 2. Pin connection for the ESP8266 ESP-01 to other components

To connect the microcontroller to the front end application, we need to utilize a Wi-Fi module (ESP8266 ESP-01) to connect through TCP/IP protocol. Appendix B shows the list of AT commands necessary to set up remote server connection to LabVIEW. We have the ability to call soft serial library to set digital pins 2 and 3 for the ESP8266 as RX and TX pin to not interfere with ATmega328p when you upload program through the actual RX and TX pins. For our purpose of the project, we will not require two GPIO that are available on the ESP8266 and do not need to make any connection to those ports.

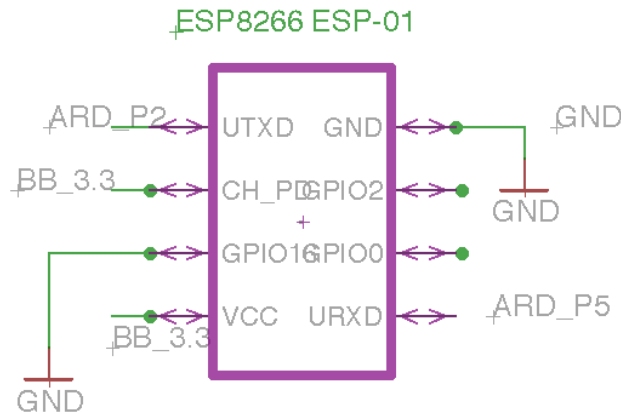


Figure 4. ESP8266 ESP-01 Circuit Schematic

3. 3-Axis Accelerometer (ADXL335)

Input: 1.8 to 3.6 VDC, 350mA input current

Output: Xout, Yout and Zout pins to send data to the microcontroller (ATmega328P)

Pin	Function	Connection
6	GND, ground	to ground of microcontroller
8	Zout, Z-axis data line	to analog input pin 2 of microcontroller

10	Yout, Y-axis data line	to analog input pin 1 of microcontroller
12	Xout, X-axis data line	to analog input pin 0 of microcontroller
14	Vcc, Input voltage	to Vcc of ATmega328P

Table 2.1 Pin connection for the ESP8266 ESP-01 to other components

The digital 3-axis (x, y and z) acceleration data from ADXL335 is interfaced with the microcontroller's analog input pins (0,1 and 2) for data analysis. The innate feature of this accelerometer chip allows to detect the movement of the hanger; if hanger's movements are detected by the accelerometer, microcontroller will receive the data and determine whether to go into a low-power mode or into the active mode. This will automatically adjust the power consumption where it will allow the hanger to increase in battery life.

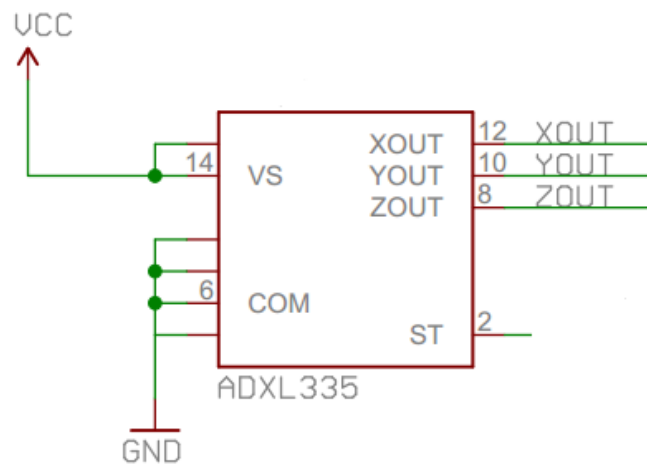


Figure 4.1 ADXL335 (3-axis accelerometer) Circuit Schematic

2.2.4 User Interface(Consumer)

1. LCD Display (2.8" SPI TFT LCD)

Input: +3.3V power input, one clock line, one product data transfer line, one slave select line and one 'Like' button GPIO

Output: one product data line to microcontroller

In the consumer user interface of the hanger, LCD will display retail price, sale price, size and banner etc.

LCD (2.8 inch TFT Serial SPI LCD) - LCD is capable of displaying numerous information consumer desires to learn about the products, which may include price, size, clothing composition, and extra information (clearance, new collection, etc). Hanger implements a Wi-Fi module that is connected to the wireless router of the retail shop, which allows internet connection to the computer. A website with input parameters can control the information displayed on the LCD.

Pin	Function	Connection
1	VCC, digital +3.3v supply	to VCC of ATmega328P
2	GND, ground	to GND of ATmega328P
3	CS, SPI slave select line	to SS of ATmega328p
4	Reset signal	to ATmega328p
5	D/C signal	to ATmega328p
6	SDI, SPI data line	to MOSI of ATmega328p
7	SCL, SPI clock line	to SCK of ATmega328p
8	LED, backlight +3.3v power supply	to OUT of TPS63030 Buck booster
9	SDO, SPI data line	to MISO of ATmega328p

Table 3. Pin connection for the serial SPI LCD to other components

2. Push Button

Input: Physical button and switch triggers

Output: Digital signal to ATmega328p GPIO pins on the microcontroller
Buttons and switch components serve as active user input of this device.

‘Like’ Button (to ATmega328p pin 14)

Purpose:

1. ‘Like’ button is used to display the number of likes on LCD. This button will serve two purposes. First is that store owner/manager can monitor which clothing and size are most popular. Therefore, he/she can predictively order correct amount of article in particular size so that there is little inventory left before seasonal/collection change occurs.
2. For the consumers to monitor which clothing are trending to be in style when buying new set of clothes.

Implementation:

1. This button is placed besides the LCD on the hanger to track the statistical data of customer’s favorite item. The button is de-bounced so that whenever customer presses it will only count once by detecting the voltage change from 0 (idle state) to 1 (button pressed state) back to 0 (idle state) as shown in Figure 5. Below.

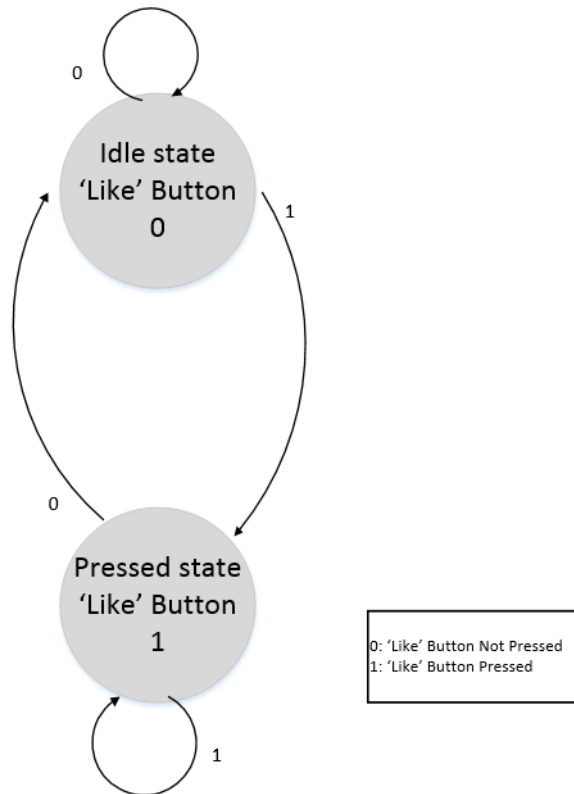


Figure 5. Finite State machine of the de-bounced “Like” Button

Reset Button (to ATmega328p pin1)

Since this project will use an external switch to control the RESET pin it is important to add a series resistance. Whenever the switch is pressed it will short the capacitor, the current through the switch can have high peak values. This will cause the switch to bounce and give steep spikes in 2ms – 10ms periods until the capacitor is discharged. By adding a series resistor between the switch and the capacitor the peak currents generated will be significantly reduced, these currents will not be large enough to generate high voltages at the RESET pin. [5] has explained this solution into reset switch connection circuit shown in Figure 6.

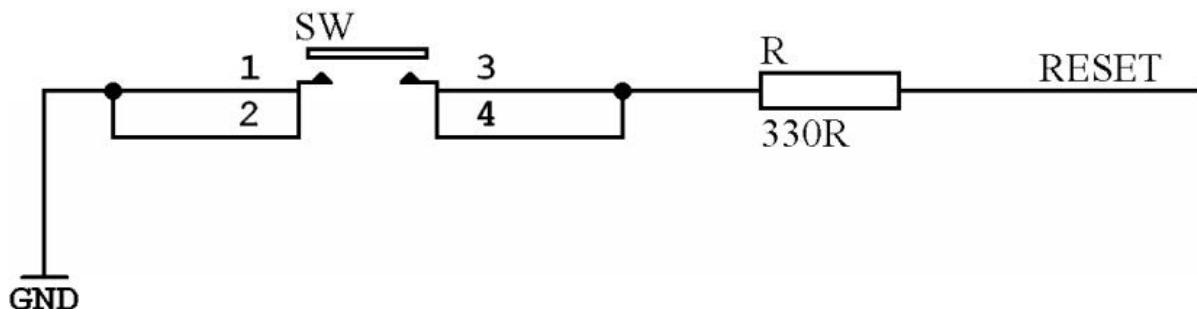


Figure 6. Switch Connection for Reset Pin

2.2.5 User Interface (Store Employee)

Developing GUI front end application for store employee to easily search and post information is essential part of the project. To achieve this with minimal front end programming experience, LabVIEW is a great way to set up a standalone executable program with an added ability of setting up a local/web server and connect hardware components through TCP/IP connection.

1. Front End Application (LabVIEW)

As shown in figure below, we can create a GUI in a file type called VI. VI has two components, which includes the GUI at the front panel and system level graphical programming in the block diagram. LabVIEW allows various customization with the user interface. The front panel is where the user would actually use to interface with the software and the block diagram shows system level description of data path and programming required to execute sequence of user interface. We could even generate a log in prompt for employees to log into to allow changes to occur, as shown in figures below.

By setting file path of excel spreadsheet that contains every item product detail store has, we could send the correct retail price, sale price, size, and a banner through TCP/IP protocol with few click of buttons.

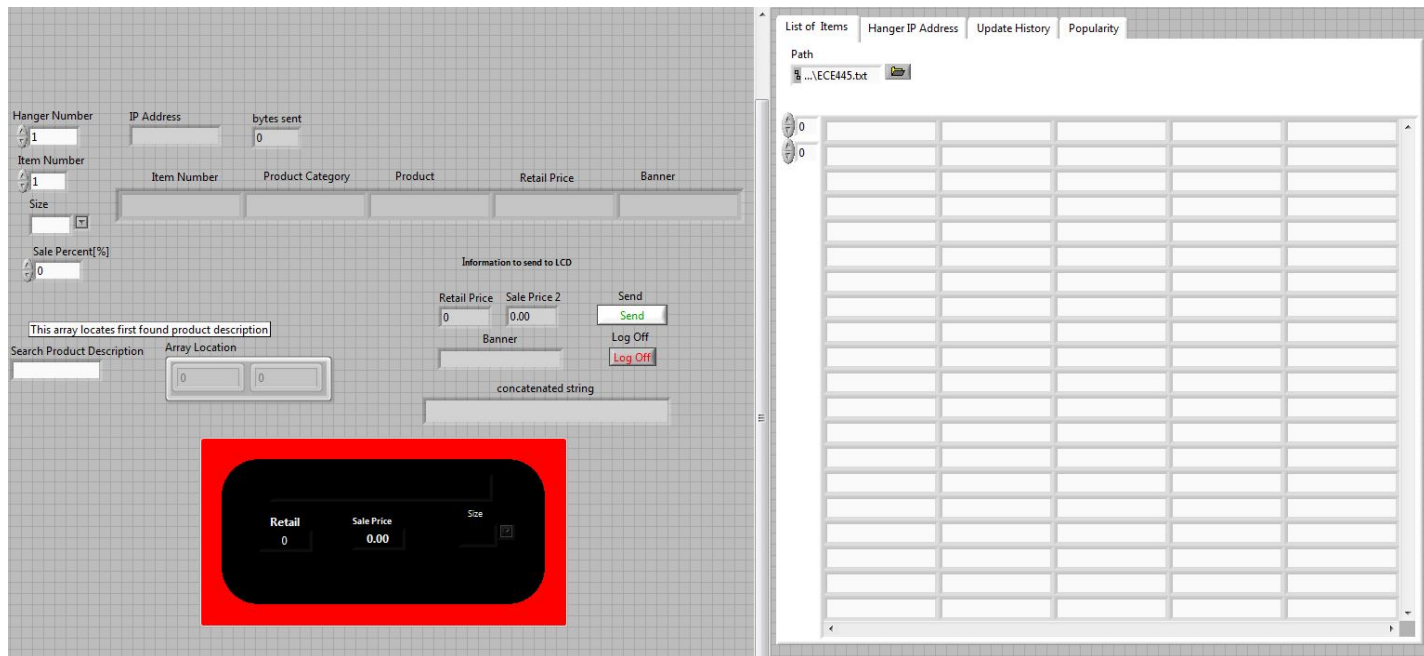


Figure 7. LabVIEW Front Panel

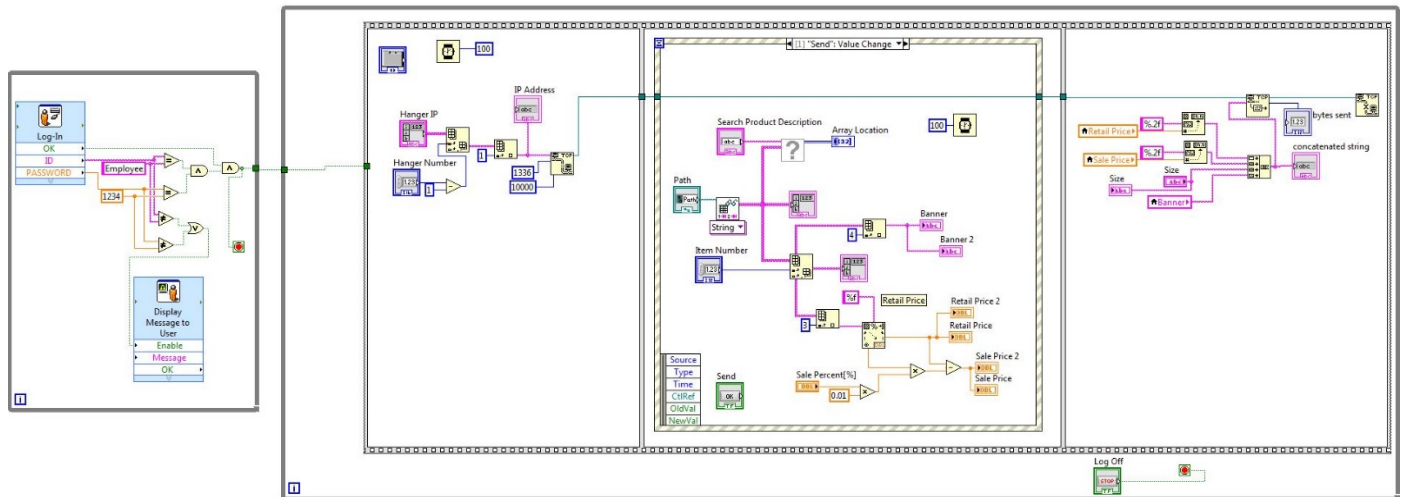


Figure 8. LabVIEW Block Diagram

2. Server (LabVIEW VI Server)

LabVIEW has added feature of setting up a VI server and a webserver to connect various hardware through TCP protocol. Transmission Control Protocol(TCP) and Internet Protocol(IP) is an essential piece of the project to transmit data across front end application to our hanger. This gives us the ability to communicate over LAN network or interconnected network. When setting up the VI server, it is important to set the correct remote port when connecting the ESP8266 TCP server to the connection port. As shown in block diagram above, you must open TCP connection first in a flat sequence structure. When the TCP connection opens, we would need to loop through an event case to poll user input of submit button. When this submit button is pressed, the loop allows TCP write to the ESP8266, in which it sends strings of information necessary to post onto LCD screen.

2.4 Calculation and Simulation

2.4.1 Power Consumption

In order to have an estimate of how long our prototype can run without charging, it is highly important to do an in-depth analysis of power consumption. Table below shows various components that require power and its power consumption [7].

As we have learned in previous power courses, mAh rating in battery refers to its ability to provide specified rating of mA in one hour. For example, the battery we plan on using has a capacity of 2000mAh. This ensures 2A of current for one hour. With that said, we can perform an analysis to examine how long our system can function in active mode without a need to charge. First, we will perform analysis assuming there is no power dissipation in battery charger for simple analysis.

Model	Size	Input Voltage (V)	Current Consumption (A) (Maximum)	Current Consumption (standby or off)	Power (V×I) Active Mode	Power (V×I) Standby Mode
TFT Serial SPI IL19341 (Display Module)	2.8inch diagonal	3.3V	200 mA	0mA (OFF)	600 mW	0mW
ESP8266-ESP01 (Wi-Fi Module)	14.3 mm × 24.8 mm	3.3V	300 mA	100uA (Deep Sleep)	990 mW	0.33mW
ATMega 328 (Micro-controller)	0.73 inch × 1.70 inch	3.3V	4.16mA *13 = 54.08mA	0.84mA (standby)	178.464 mW	2.772mW

Table 4. Power Consumption of various devices

When you add all the maximum current consumption during active mode, we see that the system requires 554.08mA, which is capable of lasting 3.6 hours without charge with our system. In the event that the LCD is off during standby mode and we allow esp8266 to be in deep sleep, we see that standby mode only requires .94mA of current, which is a huge difference. If you consider every component in the system to be ideal without any parasitic loss, we would theoretically be able to keep the device running in standby mode for 2127.6 hours! Based on our analysis, we are able to meet our minimum requirement of keeping the device on for at least 3 hours even when all the device in the system operates in active mode.

Furthermore, it is important to take power dissipation in battery into account. From analyzing the worst case scenario of power dissipation in battery charger, we can obtain the maximum power dissipation when input voltage is at a maximum level and device transitions from precondition mode to constant-current mode. Formula for power dissipation is as follows. Note that V_{ddmax} refers to the maximum input voltage, I_{regmax} refers to maximum fast charge current, and V_{pthmin} refers to minimum transition threshold voltage:

$$Power\ Dissipation = (V_{ddmax} - V_{pthmin}) * I_{regmax}$$

Assuming 5V input voltage with +10%, minimum threshold voltage of 2.7V as outlined in datasheet, and I_{regmax} of 550mA, we see that the power dissipation is

$$(5.5V - 2.7V) * 550mA = 1.54W$$

As you can compare with power consumption of devices above, we see that the power dissipation of battery in worst case scenario poses serious issues to power efficiency.

2.4.2 Power Circuitry Calculation

When choosing resistor, capacitor, and inductor values to place inside the charge management controller (MCP73831), it is important to choose the correct analog circuitry value for accurate functioning of the chip. First, with setting the programming resistor, we can essentially scale fast charging current regulation with the formula as follows:

$$I_{reg} = \frac{1000V}{R_{prog}}$$

From this analysis, we need to set R_{prog} as $2k\Omega$ to enable charge management controller to charge battery at 500mA.

Furthermore, we need to run some calculation on buck-boost converter topology. One of the most important design choice when dealing with SMPS converters is selecting a correct inductor value for the application. When selecting inductor, it is important to take into account factors such as output voltage ripple, inductor ripple current, and others. As we have learned in power electronics class, boost mode provides higher current, which represents the critical current value to choose the inductor sizing. Following formula are hence used to determine the critical inductance value to which one should size accordingly.:

$$D = \frac{V_{out}-V_{in}}{V_{out}} = \frac{5.5 - 1.8}{5.5} = .673$$

$$I_{peak} = \frac{I_{out}}{\eta*(1-D)} + \frac{V_{in}*D}{2*f*L} = \frac{0.8}{.9*(1-0.673)} + \frac{1.8*0.673}{2*2.5E6*L} = 1.1$$

By solving out the linear equation, we obtain L value of 4E-6uH.

3. Requirements and Verification

3.1 ESP8266 - ESP01 Wi-Fi Module

Requirements	Verifications	Points
1. Must be able to connect to wireless router and TCP/IP remote port within 20m of wireless access point 2. Must be on only 4 times a day (once every 6 hours) to perform update for significant reduction of power consumption 3. Must be able to loop through “TCP Write” function from front end application and post data to respective local variables stored in ATmega328P 4. The ESP8266 must transmit data at a baud rate of 9600, which is necessary for SoftSerial to function properly	1. a) By interfacing the Arduino IDE serial monitor, post corresponding AT commands as shown in Appendix B to ensure connection has been made 20 meters away from access point. b) Test that corresponding strings of data sent from LabVIEW has been saved in designated local variable in ATmega328P by printing respective variable onto the serial monitor in the Arduino IDE. 2. a) When you turn on the device, it must perform an update on information passed through TCP/IP connection and turn ESP8266 into sleep mode. b) Check that this information is passed by reducing time to 1 minute to ensure it is able to toggle from idle state to active state every minute 3. Print updated string variable onto the serial monitor as well as the LCD to observe if each strings of data packet have successfully been transferred into respective variable as specified above. 4. a) Connect ESP8266 to serial monitor via FTDI to serial interface. b) Run the corresponding AT commands to see that the host program is able to read data at baud rate of 9600 on SoftSerial by setting your IDE setting to 9600 speed and “Both NL & CR”.	15

3.2 Microcontroller – ATmega328P

Requirements	Verifications	Points
1. The microcontroller is able to program flash memory when input voltage to the microcontroller is $3.3V \pm 5\%$	1. (a) Attach the microcontroller input supply to a power supply capable of producing voltage of 3.3V (b) Attach the USB to the computer and open Arduino Software (IDE) provided by Arduino (c) Program the microcontroller with Arduino example blinking sketch (d) Verify with the serial monitor whether it outputs correct data from the microcontroller flashed memory	25
2. The microcontroller is able to communicate with SPI peripherals	2. (a) Attach the microcontroller input supply to a power supply capable of producing voltage of 3.3V (b) Attach the USB to the computer and open Arduino Software (IDE) provided by Arduino (c) Send a string of texts at least 5 characters using the Serial monitor in the software and verify that the microcontroller is sending the same string on the serial monitor.	
3. The microcontroller is able to sense voltages via the analog pins using the onboard ADC within ranges of 0.0V-3.3V $\pm 5\%$ with a precision of 3mV $\pm 1\%$	3. (a) Attach the microcontroller input supply to a power supply capable of producing voltage of 3.3V (b) Attach a function generator on the analog input pins 3,4 and 5 on the microcontroller to test ADX reading at each voltage level from 0V to 3.3V at a 300mV increment (c) Attach the USB to the computer and open Arduino	

	Software (IDE) provided by Arduino and flash the controller with the code provided in Appendix D. (d) Confirm that the ADC value changes accordingly as accelerometer is moved in the X,Y and Z directions	
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3.3 Display Module – 2.8 inch (diagonal) TFT SPI LCD

Requirements	Verifications	Points
- Voltage input to the 2.8 inch (diagonal) TFT SPI LCD is 3.3V - LCD displays ASCII text from microcontroller by having correct pin connections based on Table 3.	- Measure the voltage across the V_{CC} port (Pin1) which is connected to the V_{CC} of ATmega328P (a) Program microcontroller based on Appendix C. (b) Send text to LCD module (c) Ensure text sent fills character TFT SPI LCD and that all characters are displayed where expected.	10

3.4 Power Adapter

Requirements	Verifications	Points
120V AC to 5V $\pm$ 0.5V DC and output current of 500mA $\pm$ 50mA in active charge state	a) Connect power adapter to 10ohm power resistor in series with power rating of 3W or greater to ensure power rating is met to specification b) Place voltage probe connected to the oscilloscope across the + terminal and – terminal of the resistor. c) Voltage across resistor should confirm to be 5V$\pm$0.5V. d) Place current transducer on the input line to the + terminal of resistor to confirm output current level of 500mA$\pm$50mA.	15

2. Input current 500mA $\pm$ 50mA during peak charging phase on each DC male output port	2. Use current transducers to measure current through corresponding DC male output port meets the specified requirement when charging. Refer to data sheet for when trickle charge occurs, as the charging current decreases as battery voltage increases	
3. It needs to detect when the charger plugs into the device	3. a) Place a voltage probe across pin 3 of the DC barrel jack(female) plugged into a digital multimeter. b) When the male dc jack is unplugged, the voltage reading should be $0\pm0.3V$. c) When male dc jack is plugged in, the voltage reading should be $3.3V\pm0.3V$. d) Digital I/O pin 6 should register the sense pin voltage and power into sleep mode when device is plugged into the charger	

3.5 Lithium Polymer Battery

Requirements	Verifications	Points
1. 3.7V Nominal Voltage with minimum voltage level of 3.0V and charge cut-off voltage of 4.2V for longevity of battery life.	1. a) Place voltage probe across the + and – terminal of the lithium battery. b) Observe that the battery does indeed discharges current to its minimum specified voltage and as it charges current to its maximum specified voltage	10
2. Temperature must not exceed 60 degrees Celsius to ensure safety	2. Use an infrared IR temperature digital gun pointed on the center of the lithium battery to ensure battery temperature does not exceed specified temperature in datasheet when operating with all device in active mode for 1 hour.	

3.6 Power Converter

Requirements	Verifications	Points
1. Buck-Boost converter ((3.0-4.2)V to 3.3V $\pm$ 10%) 2. Must have high efficiency to extend battery life	1. (a) Using a voltage probe connected to oscilloscope across input voltage and output voltage of buck-boost converter, make sure the device is operating within specified range. (b) Connect a dummy load of 5ohms rated at least 3W first to ensure quality of circuit topology before connecting the real load. 2. Examine that power converter achieves efficiency above 85% through simple power analysis of Pin vs Pout by connecting input and output terminals to two multimeter available in power electronics laboratory for accurate reading of input power and output power.	5

3.7 LabVIEW Front End Application

Requirements	Verifications	Points
1. Must provide intuitive graphical interface to allow any novice user to post required information to the hanger with few simple steps. 2. Must be able to publish remote access point for securing TCP connection between PC and ESP8266. 3. Must be able to pull up all of necessary	1. Perform experiments with application on at least 3 people of different academic background to verify novice user can post information to hanger by following through simple steps outlined in front panel. 2. Verify that a remote access point has been created by posting AT+CIPSERVER command with remote port specified in the block diagram of LabVIEW (Default value of 1336 for LabVIEW). 3. a) Save the excel database file template as text delimited file and set correct file path to where the file is.	15

information required to post onto hanger through excel database.	b) Before running the VI, make sure that the correct file path has been set and run to ensure database has been pulled up on the front panel for easy access.	
4. For security purposes, only people with access ID and code should be able to make updates	4. a) As soon as the VI is running, a log-in prompt should pop up. b) When a wrong ID and password combination is typed, a warning prompt should pop up to inform user of wrong ID and password code and to try again. c) The log-in prompt should appear immediately after to deter user from accessing application without correct ID and password.	

3.8 3-Axis Accelerometer (ADXL335)

Requirements	Verifications	Points
1. Supply voltage must be between 1.8 VDC and 3.6 VDC	1. (a) Attach the accelerometer Vcc to a DC power supply at 3.3V (b) Verify that the device is active within the specified range by observing accelerometer measurements on Arduino IDE through UART communication	5
2. Accelerometer must detect an acceleration of $1g \pm 10\%$ on a single axis when completely flat	2. (a) Connect analog of the to the microcontroller (b) Align sensor completely flat along one axis (c) Verify that the microcontroller indicates high values on one side ($+1g \pm 10\%$) and values close to zero for the other sides ($0g \pm 0.1g$) (d) Pick up the hanger at different speeds (slow, medium and fast pace) and confirm that sum of change in X, Y and Z acceleration is greater than equal to 60	

3.9 Tolerance Analysis

The critical part of the design is to consume less power as possible. It is obvious that lower the voltage the lower power consumption. Typically, at 1MHz the ATmega328P draws 6.75mA @ 5V, but only 0.92mA @ 3.3V. In a similar way, lowering the frequency will also lower the power. Typically, at 8MHz the ATmega328P draws 11.68mA @ 5V, but at 1MHz it draws

6.75mA @ 5V [5]. However, if the clock frequency is too low, it could not have enough CPU cycles to do the job.

To determine how many volts per Megahertz (MHz) gives the maximum efficiency, the chart from the ATmega328P datasheet [2] shows the number of volts required for each speed:

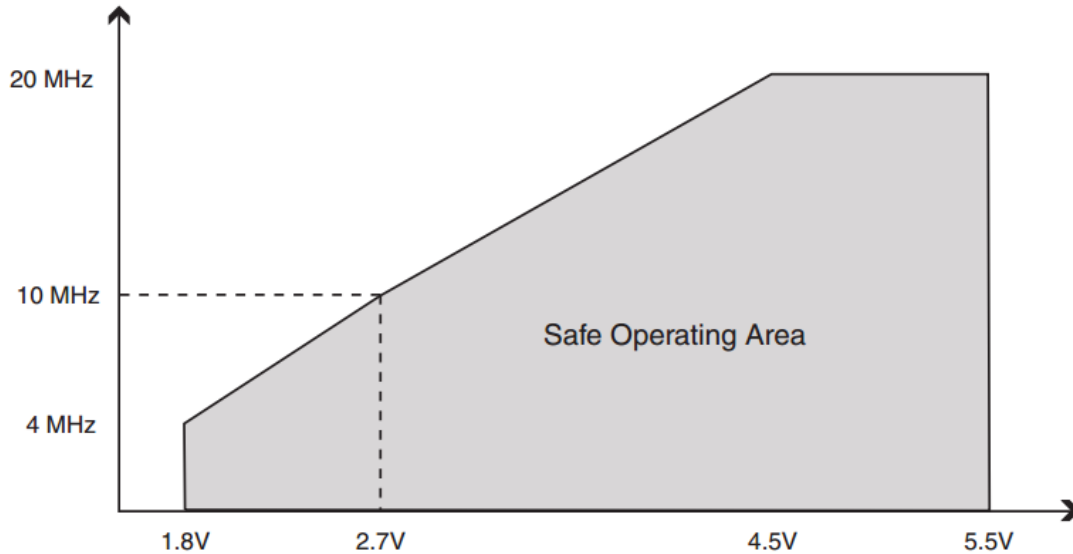


Figure 5. Maximum Frequency vs Vcc [2]

Translating into formula we see that:

- Below 1.8V : cannot operate
- Below 4 MHz : use at least 1.8V
- Between 4-10 MHz : $Volts = 1.8Volts + [(x - 4)MHz \times 0.15 \frac{Volts}{MHz}]$
- Between 10-20 MHz : $Volts = 2.7Volts + [(x - 10)MHz \times 0.18 \frac{Volts}{MHz}]$
- At 5.5V : absolute maximum supply voltage

Re-arranging the formula to calculate a maximum speed for a given voltage:

Vcc Range (Volts)	Maximum speed (MHz)
1.8 ~ 2.7	$M = 4 MHz + \frac{(V - 1.8) Volts}{0.15 \frac{Volts}{MHz}}$

2.7 ~ 4.5	$M = 10 \text{ MHz} + \frac{(V - 2.7) \text{ Volts}}{0.18 \frac{\text{Volts}}{\text{MHz}}}$
-----------	---

Table 5. Maximum speed (MHz) for a given supply voltage (V)

Higher MHz means higher data transmission speed. Since this project's microcontroller is supplied by maximum voltage of (~3.3V), from the equation derived at **Table 5.**, we can get the maximum speed:

$$\begin{aligned}
 \text{Maximum Speed (MHz) @ 3.3V} &= 10 \text{ MHz} + \frac{(3.3-2.7) \text{ Volts}}{0.18 \frac{\text{Volts}}{\text{MHz}}} \\
 &= 10 \text{ MHz} + \frac{(3.3-2.7) \text{ Volts}}{0.18 \frac{\text{Volts}}{\text{MHz}}} \\
 &= 13.3333 \text{ MHz}
 \end{aligned}$$

Summarizing voltages required for each MHz of frequency, from the formula at **Table 5** gives:

Frequency (MHz)	Voltage (Volts)
4	1.80
5	1.95
6	2.10
7	2.25
8	2.40
9	2.55
10	2.70
11	2.88
12	3.06
13	3.24
14	3.42
15	3.60
16	3.78
17	3.96
18	4.14
19	4.32
20	4.50

Table 6. Summary Table of Supply Voltage (V) For Corresponding Frequency (MHz)

4. COST AND SCHEDULE

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total Hours Invested	Total = Hourly Rate * 2.5 * Total Hours
Min Kyun Kim	\$25	200	\$12,500
Won Ho Chung	\$25	200	\$12,500
Total	-	400	\$25,000

4.1.2 Parts

Parts	Vendor	Part #	Quantity	Cost
LCD	AliExpress	F85-TFT-37445	1	\$8.06
Hanger	Illnois Maker Lab	3D Printing	1	\$0
Wi-Fi Module	Sparkfun	ESP8266-01	1	\$2
Battery	Sparkfun	PRT-08483 ROHS	1	\$12
Micro-controller	Digi-Key	ATMEGA328P-PU-ND	1	\$3.70
8MHz Crystal	Digi-Key	CTX1055CT-ND	1	\$0.38
Wire, Resistor, Capacitor,	-	-	-	Available

Inductor				through ECE service shop
PCB	-	-	1	Available through ECE service shop
Power Outlet	Ebay	PSC12R-050	1	\$5
Buck / Boost Converter	Texas Instruments	TPS63031DSKT	1	\$2.36
Charge Management Controller	Microchip	MCP73831	1	\$0.59
FTDI breakout board	Banggood	FT232RL-FTDI	1	\$3.12
DC male/female port/pin	Ebay	-	2	\$3
Total			-	\$40.21

4.2 Grand Total

Section	Total
Labor	\$25,000
Parts	\$40.21
Grand Total	\$25,040.21

4.3 Schedule

Week	Task	Responsibility
Feb 8	Finalize proposal	Chung
	Explore eagle design	Kim
	Prepare mock design review	Chung
Feb 15	Prepare design review	Chung

	Research on sensor and microcontroller selection	Kim
	Research on power supply and Wi-Fi unit	Kim
Feb 22	Purchase parts and components	Chung
	Research on software platform	Kim
	Design power supply unit	Chung
Feb 29	Basic tests on the reaction of sensors	Kim
	Program microcontroller for basic tests	Kim
Mar 7	Test microcontroller, power circuitry and peripherals on breadboard	Kim
	Design and prototype webpage interface	Chung
	Program on Wi-Fi data transmission	Chung
Mar 14	Design PCB prototype	Chung
	Assemble microcontroller and power supply	Chung
	Test sending information through software and check the correct updated results on LCD	Kim
	Finish software interface development and run test with hardware	Chung
Mar 28	Finalize the PCB design	Chung
	Elaborate the project	Kim
	Problem solving, find solutions for the issues found during the tests	Kim
Apr 4	Prepare for Mock Demo	Both
	Hardware/Software debugging	Kim
	Perform experiments to gather data for evaluation of component quality	Chung
Apr 11	Assemble microcontroller, power and sensor module together	Kim
	Make improvements based on feedback from Mock Demo and prepare for Final Demo	Chung
	Finish up with additional debugging and take inquiry of the hanger encasing	Kim
Apr 18	Make last adjustments/tuning before Final Demo	Both
	Gather and analyze data for the report	Chung
	Get feedbacks from actual users for improvements on the product	Kim
Apr 25	Continue working on final report	Both
	Prepare for final presentation and perform mock presentation	Both
	Clean up, lab check out	Both
May 2	Perform Final Presentation	Both
	Make final revision to final report and lab notebook	Both

5. SAFETY AND ETHICS

5.1 Safety Statement

The intelligent hanger is a relatively low power consuming device and naturally, there are little parts of the device that pose potential threat. One of the most important component is the rechargeable circuitry and the Lithium polymer battery. To prevent battery from overcharging,

stable grounding is required in order to avoid the device from burning. The list of important factors to consider at all times are shown below:

- Do not handle power outlet under damped conditions
- Do not charge battery above the maximum thermal operating point (60 degrees Celsius)
- Do not discharge battery below minimum safe voltage (+2.75V)
- Do not charge battery with more current than the battery can provide (1-2C)
- Do not turn on the device when wire insulation and contact points are exposed
- Do not charge battery above or below certain temperature
- Do not misconnect the battery in reverse polarity (avoid connecting positive and negative terminals to each other)
- Do not leave the battery in high temperature environment to avoid overheating and explosion
- Do not use NiMH/NiCad/lead-acid charger

5.2 Ethical Concerns

While working on this Retail Smart Hanger project, my partner and I will strictly follow the Code of Ethics that are stated on Institute of Electrical and Electronics Engineers (IEEE) webpage. These guidelines can be found in IEEE Policies, Section 7 - Professional Activities (Part A - IEEE Policies). We agree to follow all of these ethics codes and will take special precautions to the following code of ethics:

1. To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.

Since this project consist of using wall outlet voltage (120V), there is always a possibility of getting electrocuted, causing fatal damage. In order to prevent this, we will ensure that all connection wires are properly insulated and concealed at exposed points. We will initially be using lab DC power supply in our experiments for to enhance safety and reliability. In addition, since this device be on most of the day, we intend on designing and assembling the device with low-powered components whenever possible and have device be turned off when in idle state.

3. To be honest and realistic in stating claims or estimates based on available data.

Retail Smart Hanger will implement rechargeable circuitry. Various experiments must be run with our component in place to verify our requirements and provide the customers with most accurate and honest data. This will require honest and realistic attitudes in stating claims. Also, to keep the device from burning/overheating, powering data will be investigated strictly.

7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.

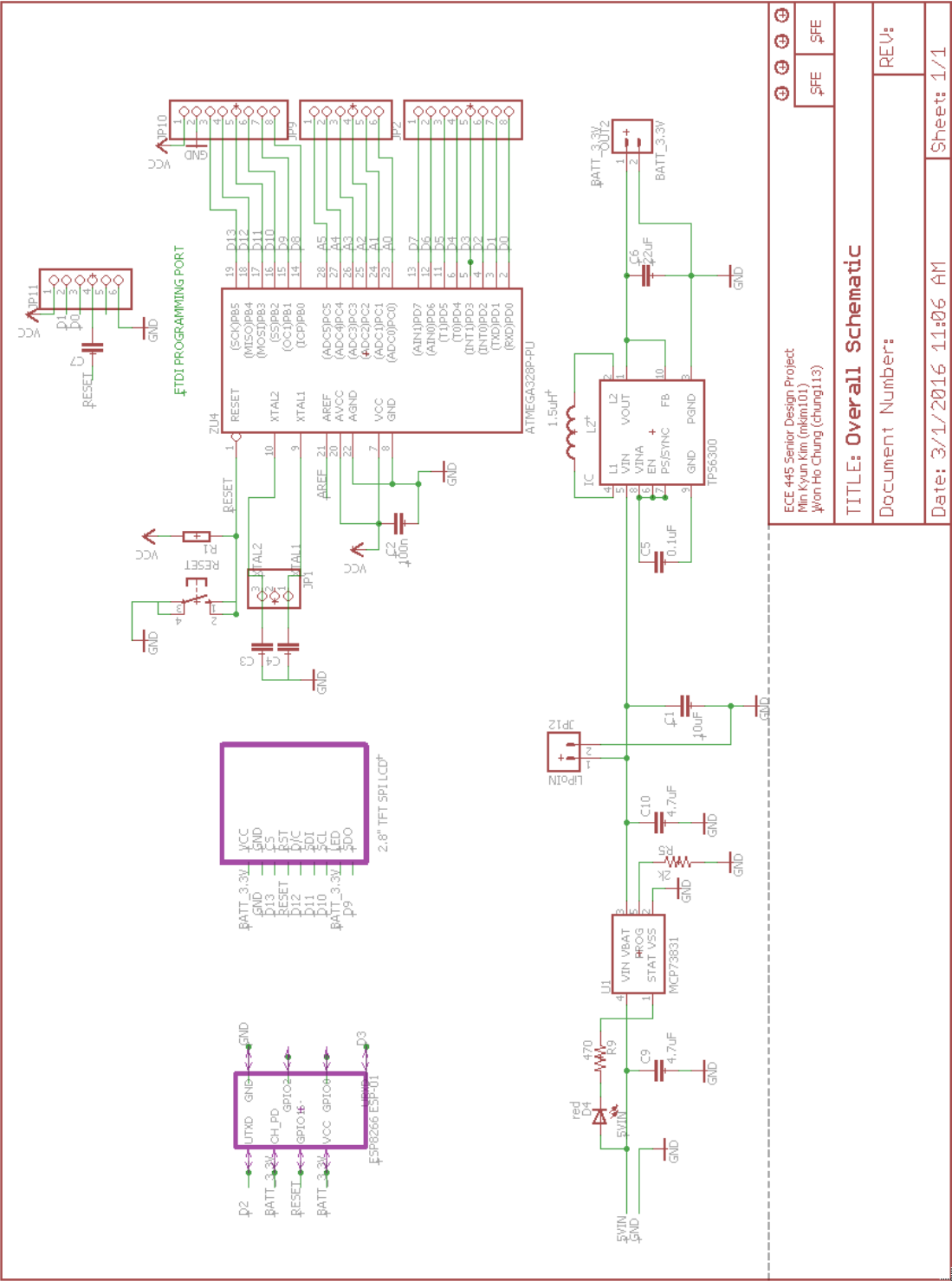
Creating an actual prototype from scratch requires extensive debugging and troubleshooting. Throughout the course of this project, seeking for productive criticism will be vital to creating a more successful product. We will be open to all critiques and advices regarding our project and will even have others try out our front end application to receive feedback.

9. *To avoid injuring others, their property, reputation, or employment by false or malicious action.*

As mentioned on Guideline #1 on code of ethics, safety is our top priority. It is important to prevent injury to user and to protect the equipment as well. Various devices that are in Senior Design Lab are properties of Electrical and Computer Engineering (ECE) department and shared among other ECE 445 classmates. When dealing with these equipment, we will pay special attention to the safety rules not to damage the devices and not to harm ourselves, just as we have learned through lab safety training.

6. Appendix

6.1 Appendix A (Overall Schematic)



ECE 445 Senior Design Project Min Kyun Kim (mkim101) Won Ho Chung (chung113)	
TITLE: Overall Schematic	
Document Number:	
Date: 3/1/2016 11:06 AM	Sheet: 1/1

6.2 Appendix B (AT Command for ESP8266 ESP-01)

- 1) Ensure AT command received correctly
 - Enter: AT
 - Display: OK
- 2) Reset state
 - Enter: AT+RST
 - Display: OK
- 3) Set module as station and access point
 - Enter: AT+CWMODE=3
 - Display: OK
- 4) Display list of available Wi-Fi networks
 - Enter: AT+CWLAP
 - Display: All surrounding Wi-Fi networks
- 5) Join Wi-Fi access point
 - Enter: AT+CWJAP= "SSID", "Password"
 - Display: OK
- 6) Enter multiple connection mode
 - Enter: AT+CIPMUX=1
 - Display: OK
- 7) Set ESP8266 to listen for connection on specific remote port
 - Enter: AT+CIPSERVER=1,"remoteportnumber"
 - Display: OK

Setting these AT commands should now set ESP8266 to listen for connection coming from LabVIEW.

6.3 Appendix C (Code for Interaction Between ATmega328 - LCD on Operating Voltage)

```
#include "SPI.h"
#include "Adafruit_GFX.h"
#include "Adafruit_ILI9341.h"

#define TFT_DC 9
#define TFT_CS 10

// Use hardware SPI (on Microcontroller, #13, #12, #11) and the above for CS/DC
Adafruit_ILI9341 tft = Adafruit_ILI9341(TFT_CS, TFT_DC);

void setup()
{
    Serial.begin(9600);
    tft.begin();
}

unsigned long testText()
{
    tft.fillScreen(ILI9341_BLACK);
    unsigned long start = micros();
    tft.setCursor(0, 0);
    tft.setTextColor(ILI9341_RED);
    tft.setTextSize(4);
    tft.println("BLACK FRIDAY SALE");
    tft.println();

    tft.setTextColor(ILI9341_WHITE); tft.setTextSize(2);
    tft.println("Retail Price : $1000");
    tft.println();

    tft.setTextColor(ILI9341_WHITE); tft.setTextSize(2);
    tft.println("Sale Price : $500");
    tft.println();

    tft.setTextColor(ILI9341_BLUE); tft.setTextSize(2);
    tft.println("SIZE : XSMALL");

    return micros() - start;
}
```

6.4 Appendix D (Code for Sensing the Range of Analog Input Pins on Microcontroller)

```
#include "SPI.h"
#include "Adafruit_GFX.h"
#include "Adafruit_ILI9341.h"

#define TFT_DC 9
#define TFT_CS 10

const int xpin = A0;           // x-axis of the accelerometer
const int ypin = A1;           // y-axis
const int zpin = A2;           // z-axis (only on 3-axis models)

// Use hardware SPI (on Microcontroller, #13, #12, #11) and the above for CS/DC
Adafruit_ILI9341 tft = Adafruit_ILI9341(TFT_CS, TFT_DC);

void setup()
{
  Serial.begin(9600);
  tft.begin();
}

void loop()
{
  tft.setRotation(1);
  testText();
  while(1)
  {
    Serial.print(analogRead(xpin)); // print the sensor values on x-position:
    Serial.print("\t");             // print a tab between values:
    Serial.print(analogRead(ypin)); // print the sensor values on y-position:
    Serial.print("\t");             // print a tab between values:
    Serial.print(analogRead(zpin)); // print the sensor values on z-position:
    Serial.println();
    delay(100);                     // delay before next reading:
  }
}
```

7. REFERENCES

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