Smart Tool Chest

Design Review

Group 41

By: Kevin Boldingh and Devansh Solanki

TA: Stephen Hall

ECE 445

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1. Introduction

1.1 Statement of Purpose

Frequently, at a large lab or workshop, there is a community tool chest. Many times, tools are misplaced or lost and some employee must then spend company time tracking down these tools. In some cases, a tool chest attendant is necessary to manage tool check-in and checkout. We are designing an automated tool chest system which would eliminate any need for a tool chest attendant or checkout sheet, since it would allow automatic tracking and accountability for missing tools, by managing tool inventory, logging user identity, and even monitoring frequency of use. The product would employ smart pads to monitor tool presence, a magnetic stripe reader to verify user identity, and an LCD touch screen for user interaction. This system would be purchased already integrated into a tool chest, rather than being installed separately.

1.2 Objectives

1.2.1 Goals & Benefits

- Automatically monitor tool chest inventory
- User interface allows users to quickly determine whether a tool is present
- Display shows which user checked out a tool if it is no currently in the chest
- Provide system of accountability for removed tools, and less time required to track down missing tools
- Interface displays how often each tool is used
- Frequency tracking statistics allow better company allocation of tool budget

1.2.2 Functions & Features

- Sense tool availability with smart pads
- Allow users to see which tools are missing at a glance
- Magnetic card reader for unlocking and user tracking
- Touch screen can display user tracking information

2. Design

2.1 Block Diagram

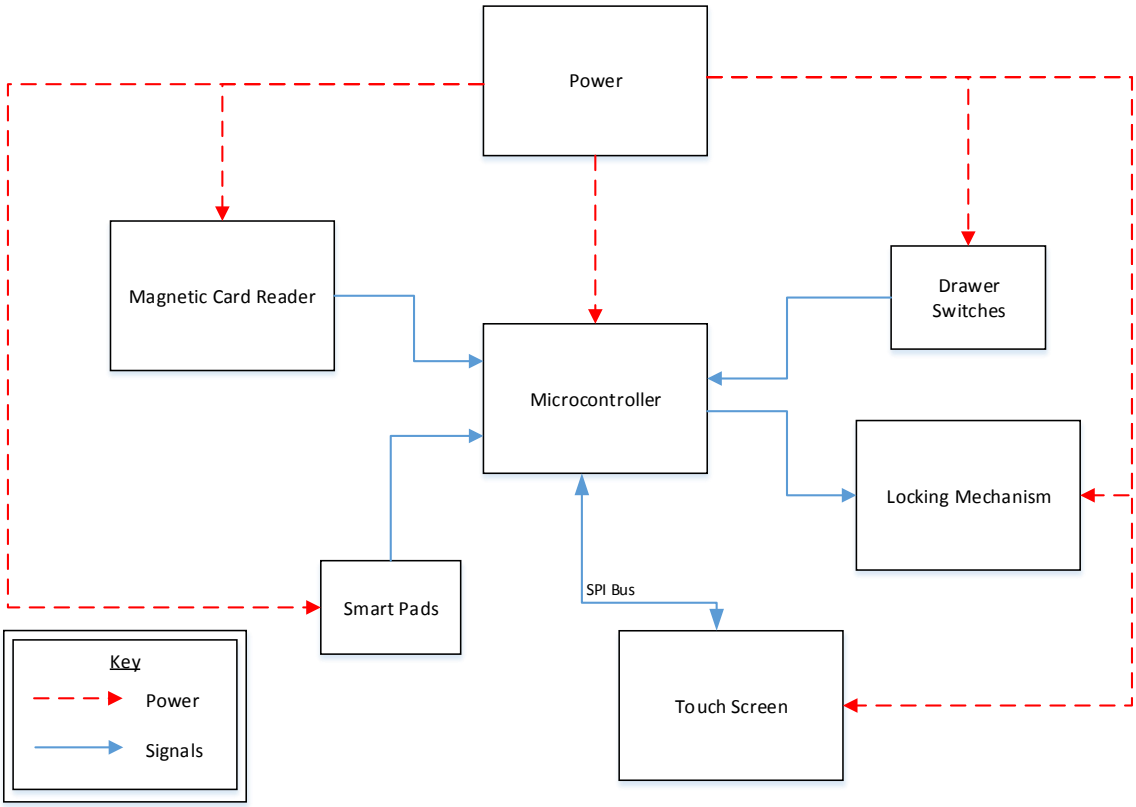


Figure 2.1: Block Diagram

2.2 Block Descriptions

2.2.1 Power

The power source will use a wall outlet. We will convert the 120V AC source to 5V DC using an off-the-shelf power adapter.

2.2.2 Microcontroller

The microcontroller serves as the central hub for IO as well as the decision making part of the system. It receives input from the smart pads, drawer switches, the card reader, and the touch screen to make decisions about what tools are present in the tool chest, whether to lock the chest, and what data to display on the touch screen.

2.2.3 Smart Pads

We will use smart pads to track which tools are currently within the tool chest. These 'smart pads' will be of our own design, consisting of small switches covered with layers of hard plastic sheets, topped off with soft foam cutouts (see Figure 2.3.5). The switches will be weighted such that they actuate with 5gf of force applied. The switches will be connected to conducting contacts on the back of the drawer that they reside in, which will conduct when the drawers are closed. This design will allow the data from the drawers to be sent to the microcontroller only when the drawers are closed. It is unnecessary to update every state change of the tools, the only information that is required is which tools are missing when the drawers are finally closed.

2.2.4 Magnetic Card Reader

The magnetic card reader will serve as an authentication tool to indirectly control the locking mechanism on the tool chest, through the microcontroller. It will also track the user's identity as they add and remove tools from the tool chest. The microcontroller will require a card reader input to unlock the chest after 30 sec of inactivity. Tools removed after the chest is unlocked will be labelled as taken out by the owner of the card. The name of person responsible for removing the tool will be shown on the touch screen next to the entry for that tool.

2.2.5 Locking Mechanism

The locking mechanism will accept input from the microcontroller to lock and unlock the tool chest. The mechanism itself includes a servo, which will have an arm attached to it to unlock the chest drawers, using parts of a built in key-lock (see Figure 3.2.6). The magnetic card reader will provide the information necessary for the microcontroller to decide the state of the lock.

2.2.6 Touch Screen

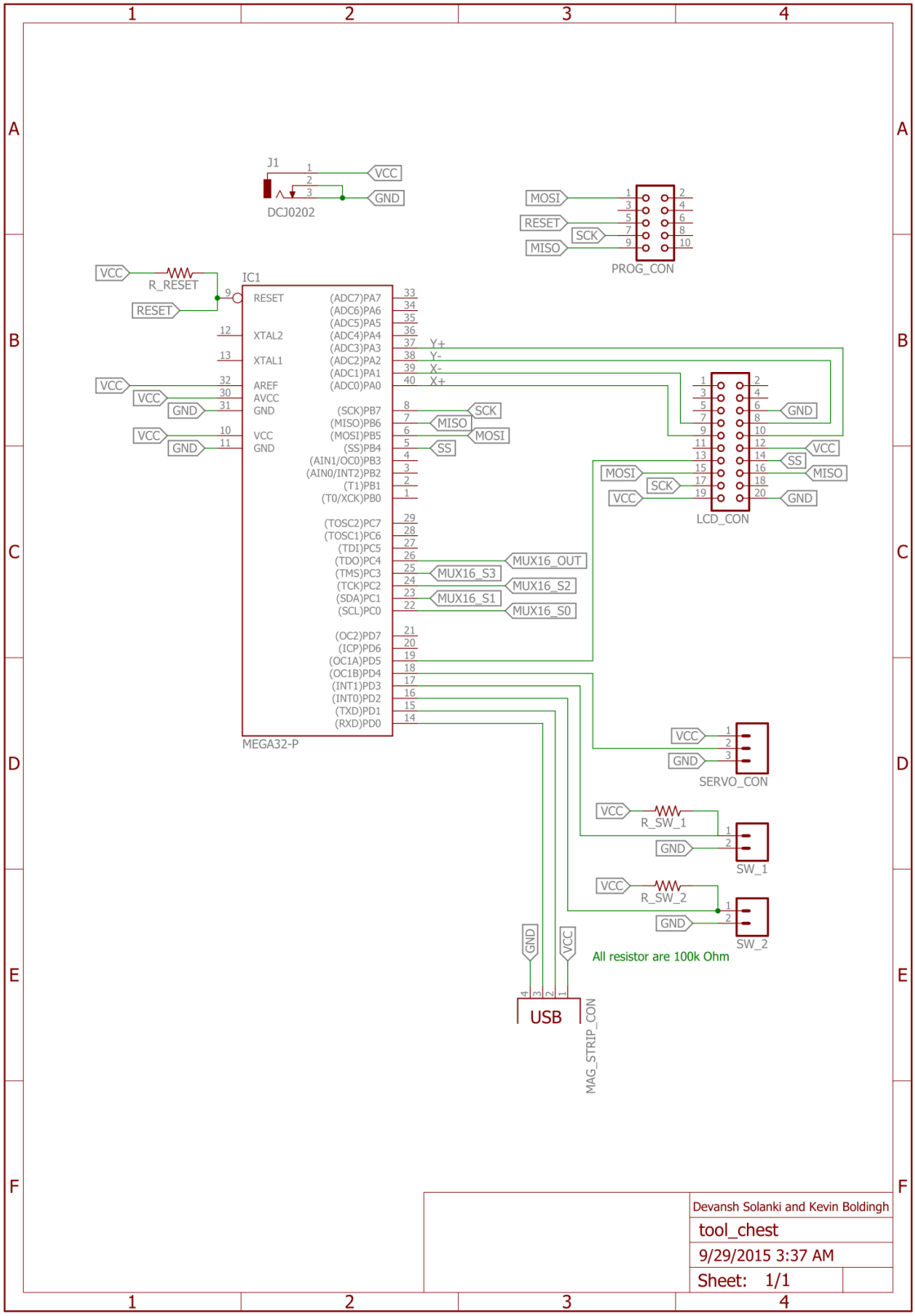
The touch screen allows the user to interact with an on-board application to add tools and users, check the inventory, and view tool statistics. The screen includes touch 5 buttons and a list of tool inventory. The touch screen will communicate over the SPI bus and will communicate exclusively with the microcontroller.

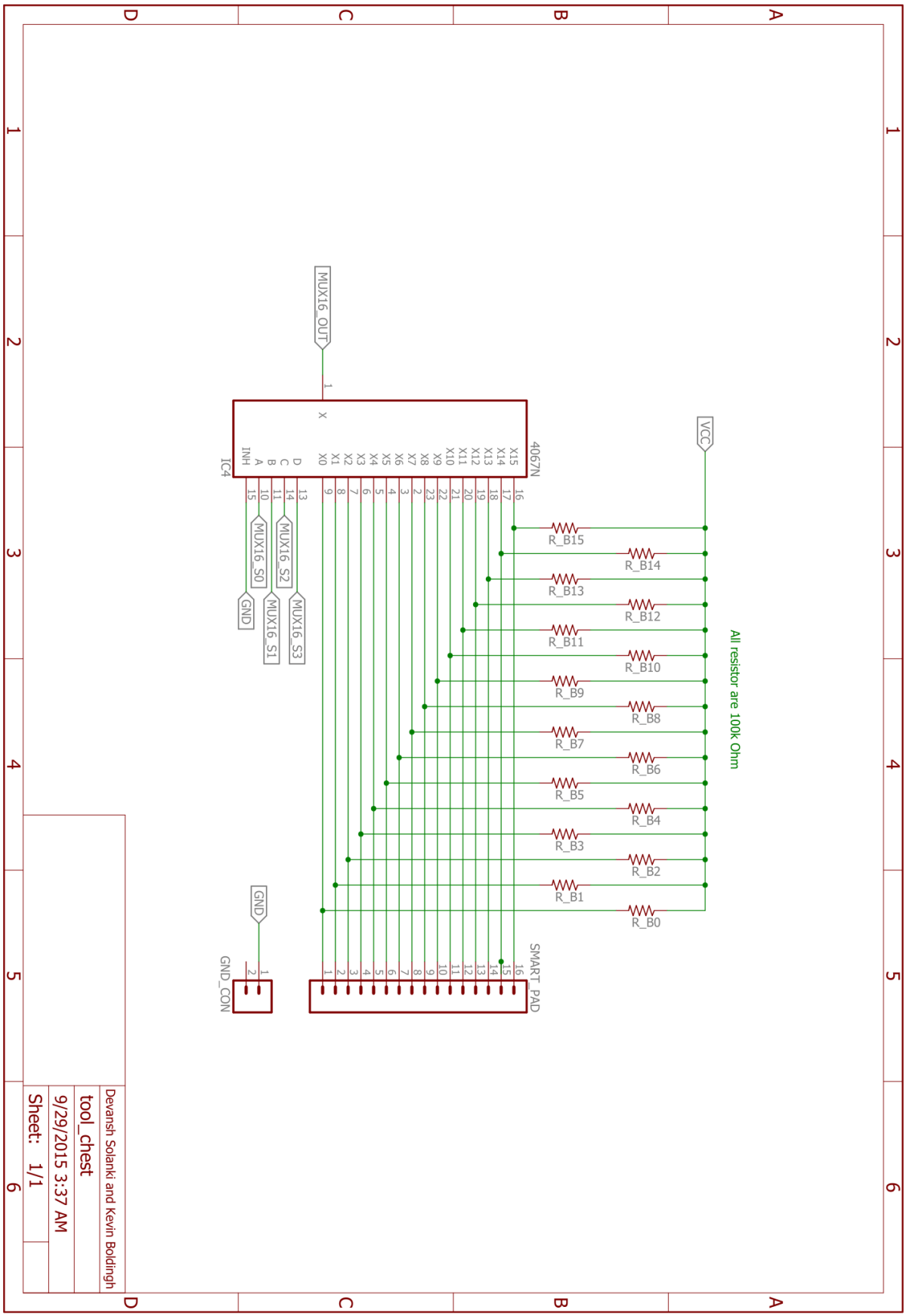
2.2.7 Drawer Switches

The drawer switches allow the microcontroller to detect whether the drawers are open. In order to prevent multiple tool state changes while the drawer is open, the state of each tool will only update once the drawer has been closed. The switches will be located behind the drawers inside the case in order to be depressed when the drawers are closed. The switches themselves are push button switches and will be depressed by a spring attached to the back of each of the drawers when they are closed.

2.3 Schematics and Diagrams

2.3.1 Main Circuit Schematic




A
B
C
D
1
2
3
4
5
6
MUX16_OUT
IC4
4067N
VCC
All resistor are 100k Ohm
R_B15
R_B14
R_B13
R_B12
R_B11
R_B10
R_B9
R_B8
R_B7
R_B6
R_B5
R_B4
R_B3
R_B2
R_B1
R_B0
MUX16_S0
MUX16_S2
MUX16_S3
MUX16_S1
GND
SMART_PAD
GND_CON
Devansh Solanki and Kevin Boldingh
tool_chest
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Sheet: 1/1

2.3.2 Tool Chest Top View

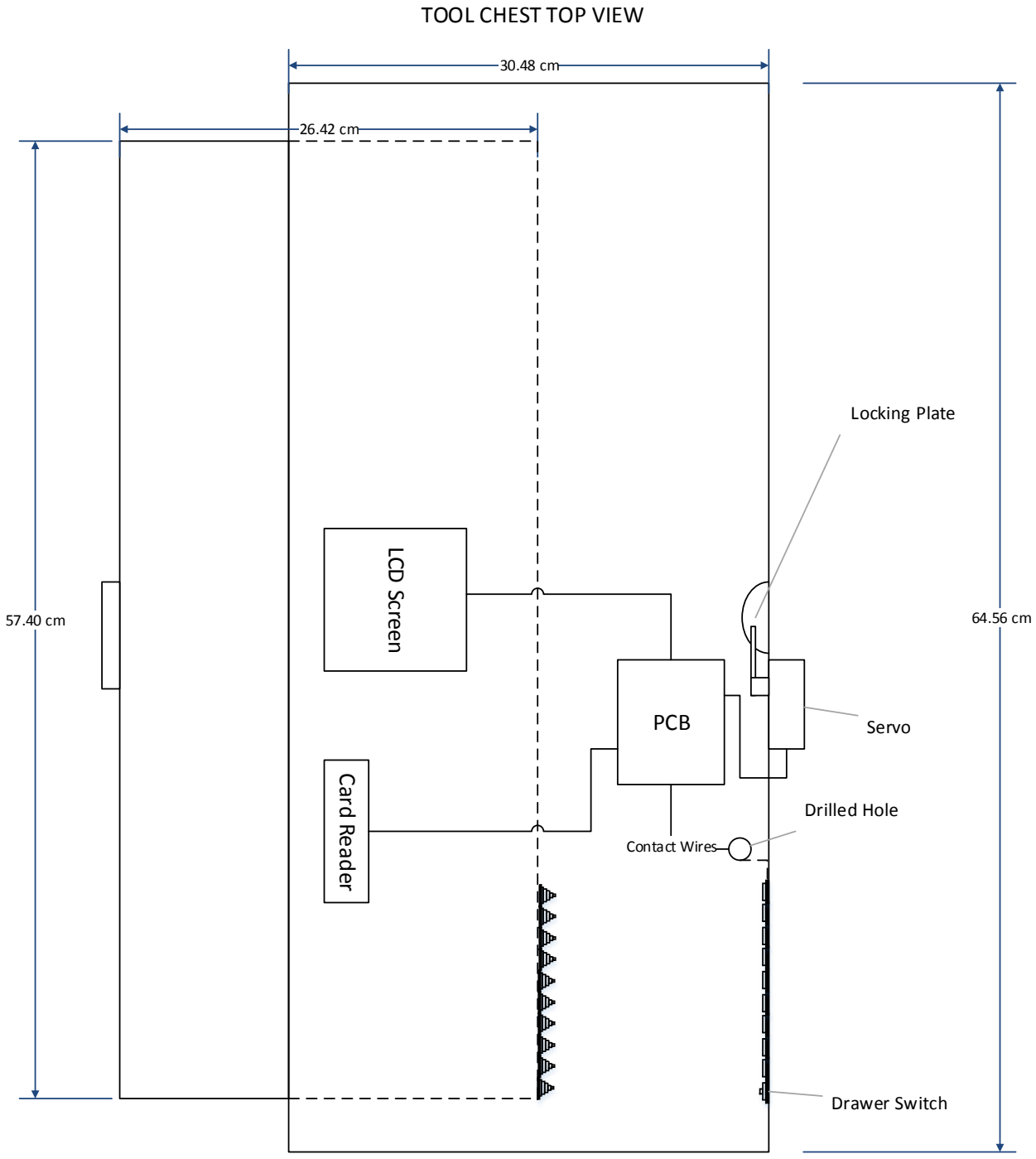


Figure 2.3.2: Tool Chest Top View

2.3.3 Drawer Top View

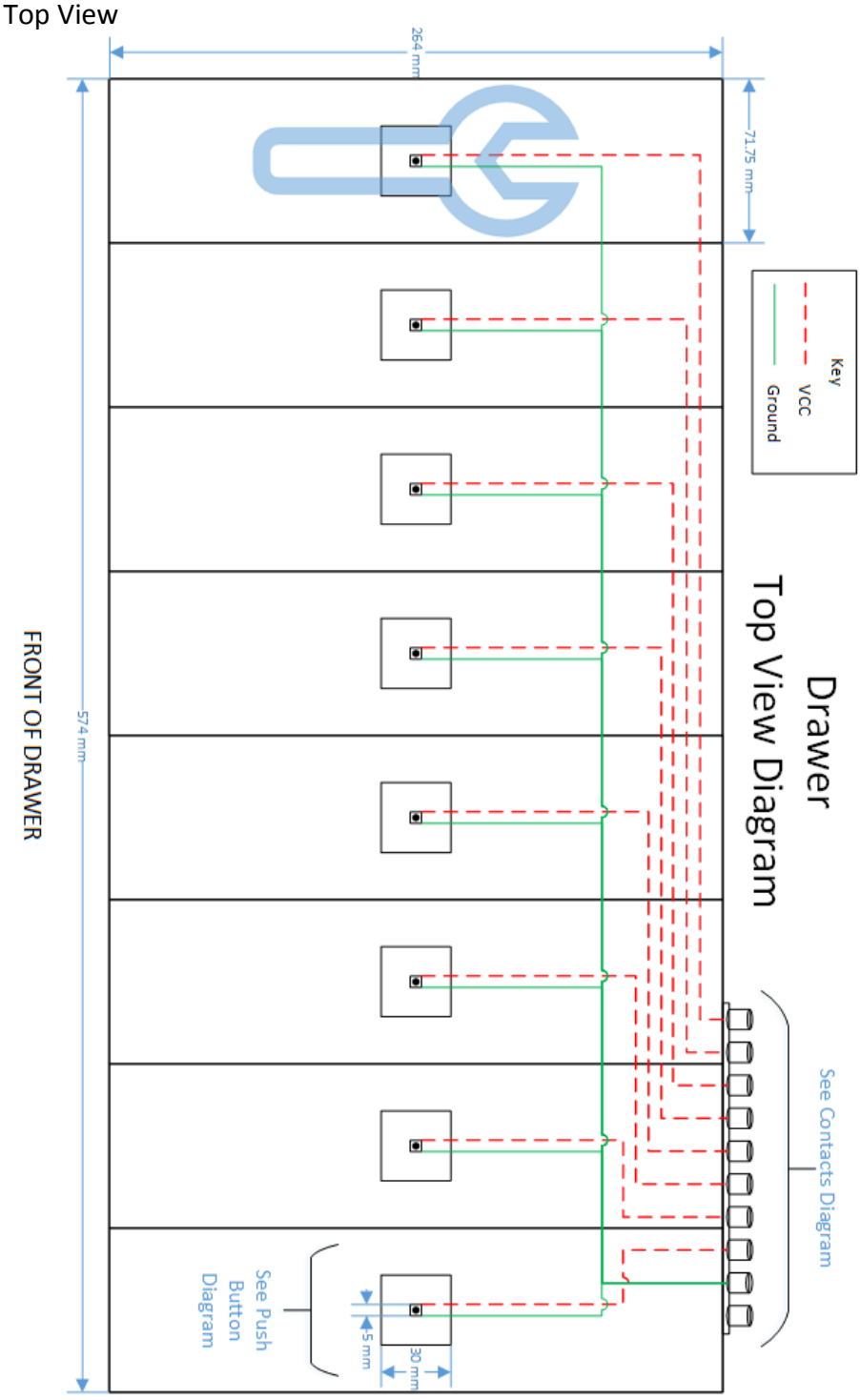


Figure 2.3.3: Drawer Top View Diagram

The above diagram shows the layout of both drawers. Drawers will each contain 8 pads upon which tools will be placed, as shown. On the back of the drawer is a 10 spring contact plate which allows data from the pads to be sent back to the microcontroller.

2.3.4 Back View of Drawer

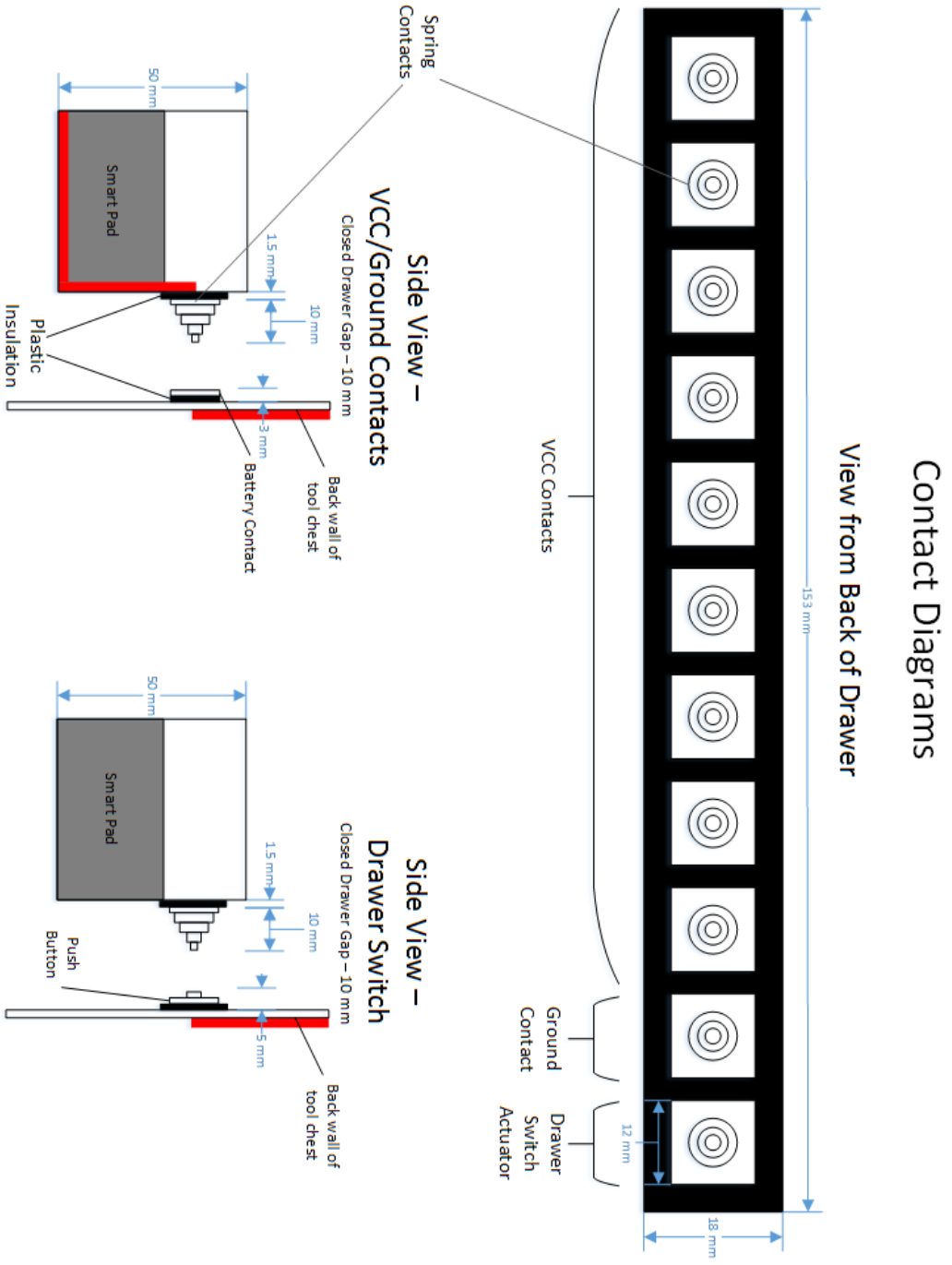


Figure 2.3.4: Contact Diagram

The above diagram shows the layout the conducting contacts on the backs of the drawers. Eight of these contacts will be used to provide power to the switches, one will be for a shared ground, and one serves only to press the drawer switch located at the back of the chest. Contacts are mounted on a plastic plate 3mm apart. All contacts are insulated from the case using plastic.

2.3.5 Smart Pad Architecture

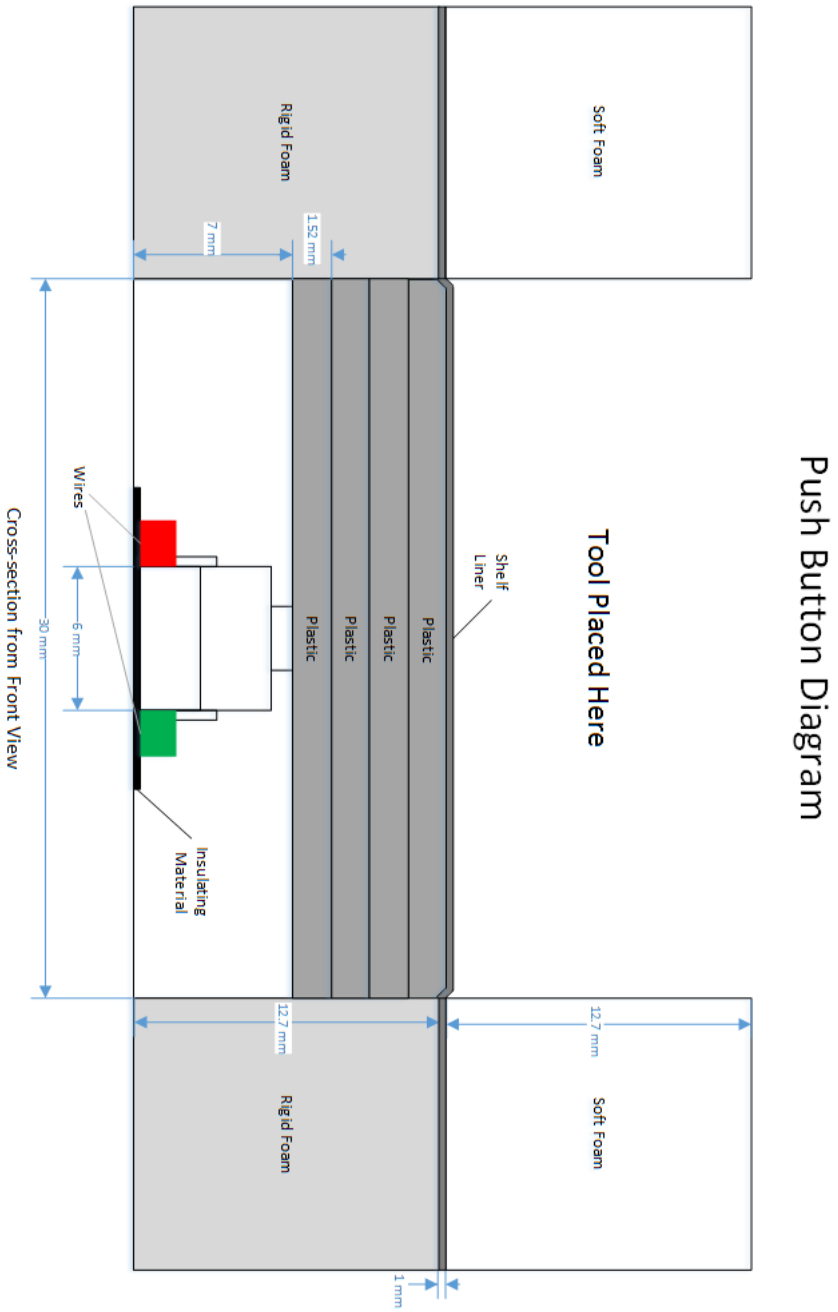


Figure 2.1.5: Smart Pad

The diagram above depicts the architecture of the smart pads. The push button in the diagram is the core component of the pad, topped by plastic and foam. The shelf liner is purely aesthetic. A tool will be placed in between the soft foam padding (the foam will be cut into the shape of that tool). The plastic will be attached to the foam using glue.

Figure 2.3.6 Servo Mounting Diagram

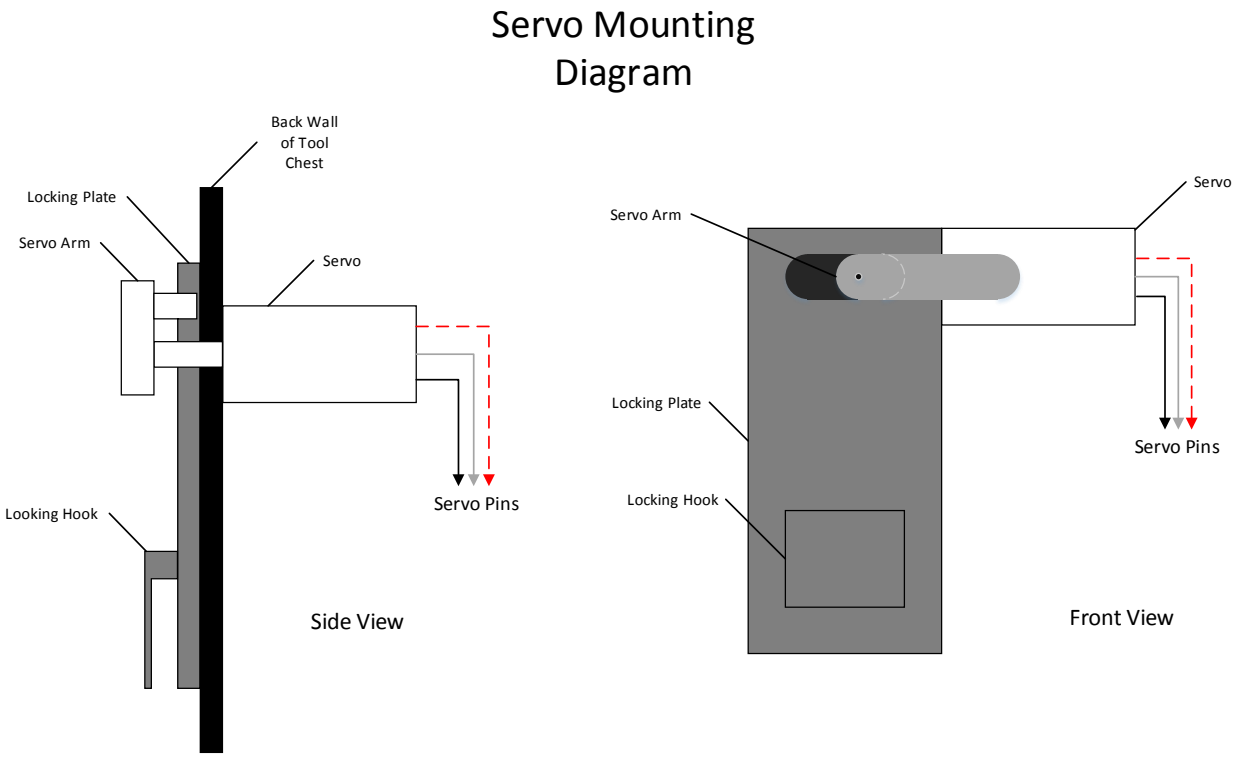
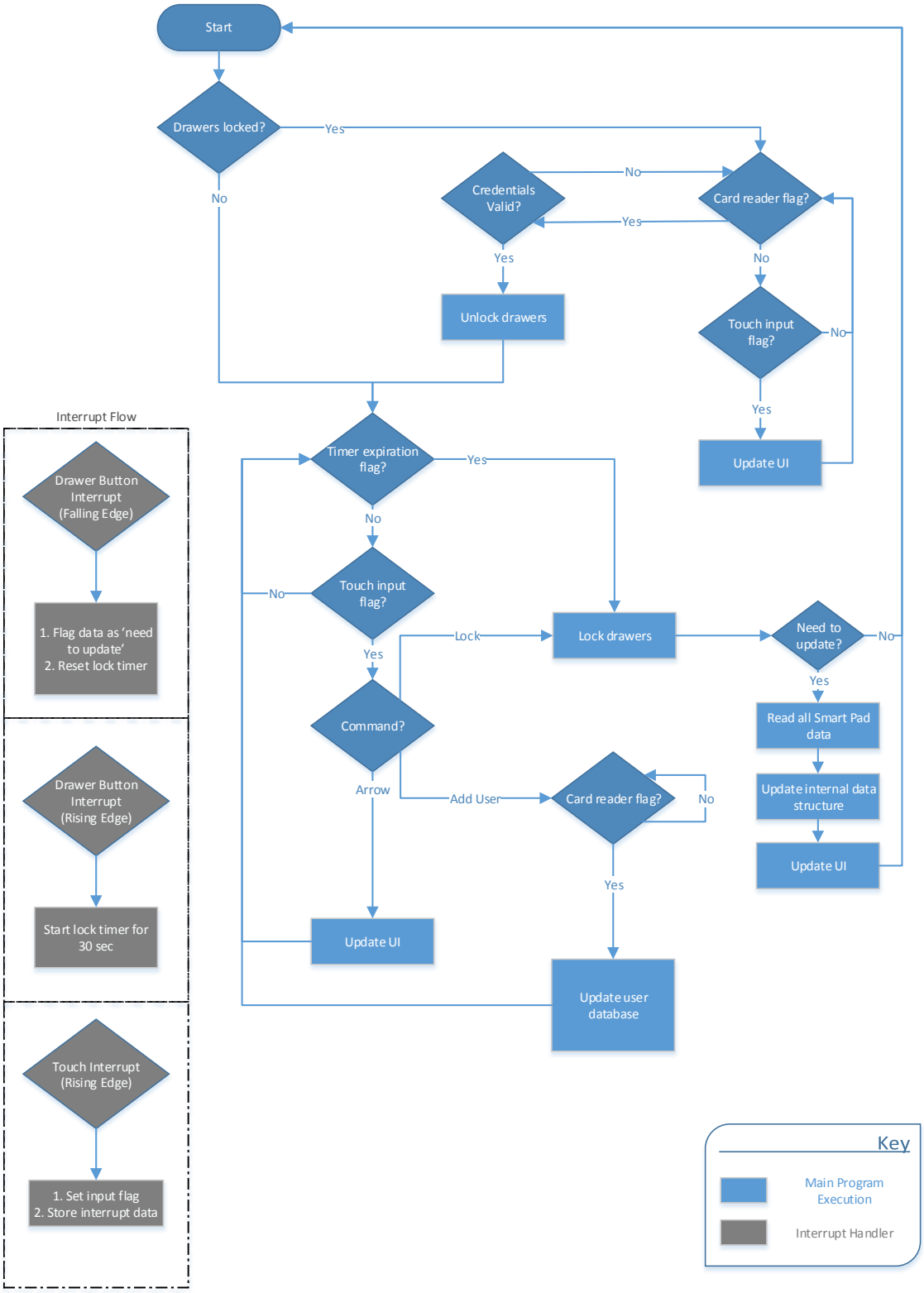


Figure 2.3.6: Servo Mounting Diagram

This figure shows the servo that locks and unlocks the tool chest. It includes an arm that attaches to the existing locking mechanism.

2.4 Software Flowchart



2.5 LCD User Interface Design

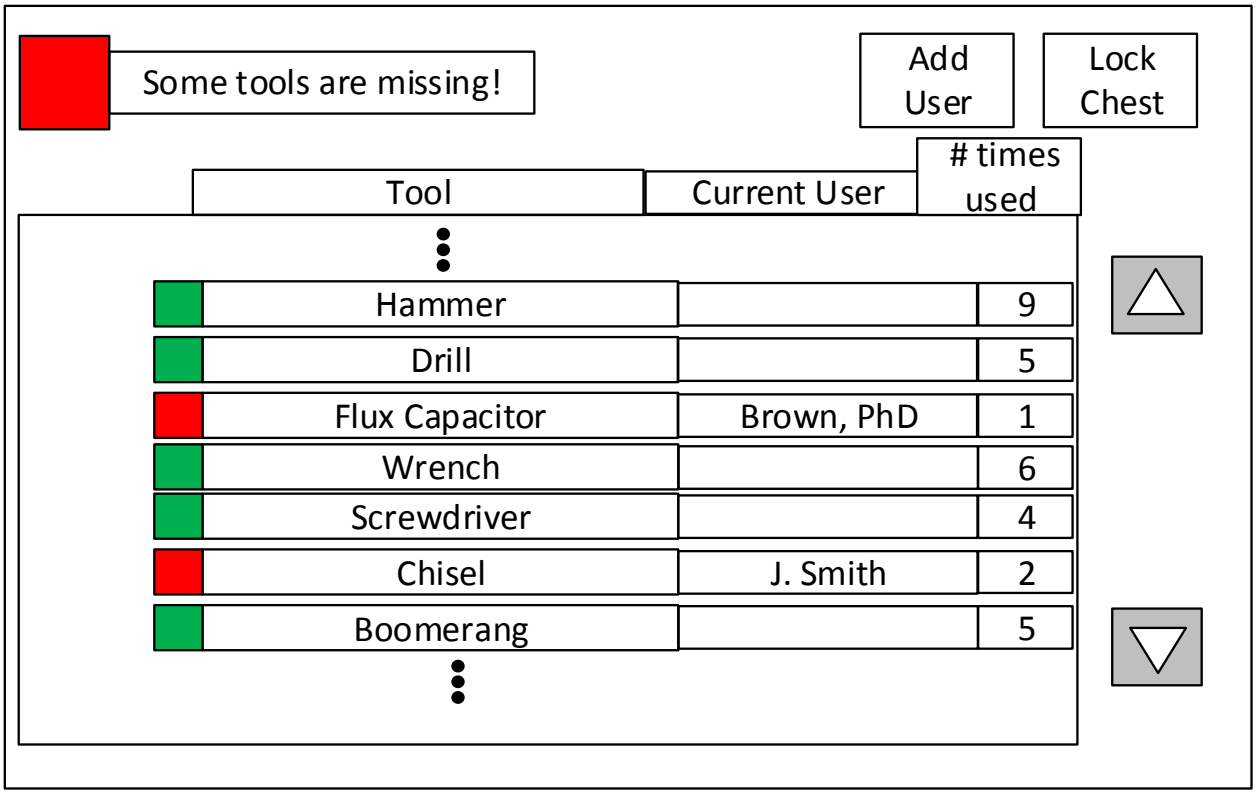


Figure 2.3: UI Design

Displayed above is the design for the user interface for the touch screen. Most notable is the list of tools in the center of the interface, which allow users to monitor the inventory. There are 5 buttons that users can use to input commands into the system: two arrow keys and the 'Add User' and 'Lock Chest' buttons. The 'Add User' button requires a user to swipe a card through the stripe reader to assign credentials to that name. The 'Lock Chest' button is an alternative to the automatic lock function (chest will lock after 30 sec of inactivity), and will send a signal to the servo to lock the chest. The arrow keys simply allow users to view the entire list of tools.

3. Block Level Requirements and Verification

3.1 Requirements and Verification Table

Component	Requirement	Verification	Points
Power:	a. Supply 5V +/- 0.2V b. Supply 1A +/- 0.1A	a. Use a digital multimeter in parallel with the power supply to measure its voltage and verify it is 5V +/- 0.2V b. Use a digital multimeter in series with the power supply to measure its current and verify it is 1A +/- 0.1A.	10
Microcontroller:	a. Must be able to output high voltage greater than 1.155V b. Must be able to output low voltage less than 0.99V	a. Use a digital multimeter in parallel with the microcontroller pins to measure that high voltage is at least 1.155V b. Use a digital multimeter in parallel with the microcontroller pins to measure that low voltage is at most 0.99V	25
Smart Pads:	a. Must be able to tell when a tool is placed on top of the pad (switch must be depressed) b. Must be able to tell when a tool is removed from the pad (switch must not be depressed)	a. • Place a tool of at least 5 g on top of each of the pads • Use a digital multimeter in parallel with the switch • Verify that the multimeter reads 0 V b. • Remove any tool of at least 5g from on top of each of the pads • Use a digital multimeter in parallel with the switch • Verify that the multimeter reads 5 V	20

Drawer Contacts:	a. Contacts must conduct when drawers are closed b. Contacts must not conduct when drawers are open	a. • Place a tool on top of each smart switch. • Close the drawers • UI should update with all the tools recognized • Alternatively, use a multimeter to verify that the voltages of the switch input pins are all 0 V b. • Open the drawers. • Remove at least one tool from each drawer • UI should not update while drawer is open • Alternatively, use a multimeter to verify that the voltages of the switch input pins are all 5 V	
Magnetic Card Reader:	a. Produce consistent and accurate result when card is read b. Be able to recognize a card read error	a. • Scan the same card 10 times. • UI will display whether credentials read were recognized. • Verify the credentials read don't differ more than twice. b. • Scan the same card 10 times • UI will display if there is a card read error.	10
Locking Mechanism:	a. Servo should be able to exert at least 0.2 kg-cm (lock requires 0.18kg-cm to actuate).	a. • Use test code to tell servo to unlock chest. • Servo should be able to lock and unlock chest.	10
Touch Screen and Application:	a. Must display data from tool database	a. • Connect touch screen to microcontroller • Check touch screen to see if tool data is displayed	20

	b. Must allow user touch input	b. • Use test code for interfacing with touch screen • Touch each button on the interface and verify that buttons change color when pressed.	
Drawer Switches:	a. Voltage output of drawer switches must be 0V when drawer is closed b. Voltage output of drawer switches must be 5V when drawer is open	a. • Close drawers • Read drawer input pins with multimeter in parallel with switch • Verify output is 0 V b. • Open drawers • Read drawer input pins with multimeter in parallel with switch • Verify output is 5 V	5

3.2 Calculations

3.2.1 Actuation Weight for Smart Pads

Button requires 65gf to actuate and there are 2 layers of material covering the button

Required added weight to meet spec = 65g – weight of plastic - weight of rigid foam

Total weight of plastic = 8.8oz * 28.3495g/oz = 249.5g for 144cm^2 surface area

Plastic required = 3cm * 3cm * 0.1524 cm = 1.37 cm^3

Weight of 1.37cm^3 of plastic = 9cm^2/144cm^2 * 249.5g = 15.6g

Required added weight to meet spec = 65g – 15.6g*4 = 2.6g < 5g

If the button actuates at this weight, we are prepared to drill holes in the plastic to reduce the weight until it is under the threshold.

3.2.2 Total current draw of all switches

There are 18 total switches and pads, each of which is connected in series with a 100k ohm resistor.

Maximum current draw would be when all switches are depressed, equivalent network resistance would be 100k/18 = 5555.6 ohms.

Total network current then is 5V/5555.6 ohms = 0.09mA ≈ 0.1mA

3.3 Tolerance Analysis – Power Supply

In order for our project to function correctly, the power supply must provide enough power for all of the component. We determined that the acceptable tolerance for the voltage output of this supply is 5V +/- 0.2 V since the servo motor cannot accept voltage input lower than 4.8V, and all other components have a maximum voltage ratings above 5.2V. The current minimum threshold was determined by summing all of the maximum current requirements of all of the components (refer to Table 3.2.1). The total current was 750.5mA, so we'll need to make sure our system always has that much power available. Therefore, the current supply must be 1A with a tolerance of +/- 0.1A.

Test Procedure:

When all the components are connected, use a digital multimeter in parallel with the power supply to measure the voltage around the supply and verify it is 5V +/- 0.2 V, then use the multimeter in series with power supply to measure the current flow to verify it is 1A +/- 0.1A.

Component	**Max Current Draw**
Microcontroller	0.4mA
Push Button Switches	0.1mA (calculated above)
Magnetic Card Reader	100mA
Locking Mechanism (Servo)	500mA at stall
Touch Screen	150mA
Total	**750.5mA**

Table 3.3.1

4. Cost

4.1 Labor

Name	Hourly Rate	Total Hours Invested	Total Cost
Kevin	$31.00	150	$11,625.00
Devansh	$31.00	150	$11,625.00
Total			$23,250.00

4.2 Parts

Part Name	Part Number	Quantity	Total Cost
Tool Chest	HTA-102B12	1	$49.00
Microcontroller	ATmega324PA	1	$6.15
LCD Touch Screen	Adafruit HXD8357D	1	$39.95
Magnetic Card Reader	Hi-Co MSR90	1	$18.60
Servo Motor	Hitec HS-5055MG	1	$17.99
Push Button Switches	LL1105	18	18 x $0.33 = $5.94
Power Supply	TSA1-050120WA	1	$5.00
Plastic, 12”x 12” 2 pack	B00CBWNUR0	1	$9.95
Rigid Foam, 4’ x 8’	100320356	1	$10.97
Soft Foam	CBS FS01	1	$9.34
Battery Contacts, 30 pack	B00O9XVE2M	1	$5.25
Pocket AVR Programmer	PGM-09825	1	$14.95
PCB		1	$40.00
Total			$233.09

4.3 Grand Total

Section	Price
Labor	$23,250.00
Parts	$233.09
Grand Total	**$23,483.09**

5. Schedule

Week	Task	Member
Sept 20	Write design review	Kevin
	Draw schematics & diagrams, order parts	Devansh
Sept 27	Plan layout for components in chest	Kevin
	Layout PCB	Devansh
Oct 4	Set up MCU with AVR programmer	Kevin
	Remove lock, install servo, case wiring	Devansh
Oct 11	Add RFID reader	Kevin
	Finalize PCB, solder components	Devansh
Oct 18	Connect touch screen, create UI	Kevin
	Add RFID tags to tools, test signal strength inside & outside tool chest	Devansh
Oct 25	Program touch inputs in microcontroller	Kevin
	Prepare mock demo, solve RFID connectivity issues	Devansh
Nov 1	Add card reader	Kevin
	Test entire system, Debug PCB issues	Devansh
Nov 8	Interface with servo	Kevin
	Install housing for system components	Devansh
Nov 15	Begin debugging	Kevin
	Install complete system in tool chest	Devansh
Nov 22	Complete application debugging	Kevin
	Prepare demo, debug remaining issues	Devansh
Nov 29	Work on demo	Kevin
	Finalize demo, finish debugging	Devansh
Dec 6	Write final paper	Kevin
	Create presentation	Devansh

6. Safety & Ethics

The purpose of our project is to create an automated device that includes combining a metal tool chest and electrical components operating on currents large enough to be dangerous. As such, insulating our connections is of the utmost importance and failure to do so could result in harm to the user. In addition, the foam that we use as a liner is flammable, so proper care needs to be taken that heat generated by the electrical components is managed in a way that prevents the foam from being heated. Both of these concerns are covered by article 1 of the IEEE code of ethics, namely:

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

Our product also aims to monitor user identity when checking out items, allowing for some accountability for missing tools. It is our responsibility to make sure that this logging data is accurate as it could foreseeably harm the reputation of one of its users. This concern is most aptly described by rule 1, but rule 3 can apply as well, it follows:

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

We will make sure that our product's case is properly insulated from its electrical components to avoid doing harm to its users, and that our data is reliable to avoid damage to users' reputations in accordance with the articles of the IEEE code of ethics.