

# Class Kit Vending Machine

## Conceptual Design

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### I. INTRODUCTION

Around fifty devices a day are needed by students each year for their ECE (Electrical and Computer Engineering) courses. The main emphasis of this capstone project is the design and implementation of a vending machine that can loan out devices to students while keeping track of which students have taken the devices. A student can enter their information into the machine, and it will keep track of who has borrowed each device(s). Students will be able to view and choose which gadget to remove with the help of an LED (Light Emitting Diode) equipped drawer system. Designing the entire system gives the machine the ability to meet all requirements of the customer. The machine shall comply with the following specifications of the customer.

The machine will be no taller than the average window height, which is around 2 to 3 feet, and no smaller than 2 feet in height. This allows for easy portability from the office to the student lounge at Brown Hall and vice versa. It should impact the customers and allow the office associates to be able to transport the machine where it is needed. Due to our ethical considerations, the machine will use ethernet to send data to our customers to avoid others from accessing the students' information. We have also considered including either a hash or encryption on the data sent.

To allow proper function of the machine, an MCU (microcomputer unit) to manage the data acquisition system is needed. An SQL (structured query language) database will be programmed into the MCU to hold the student ID (identification) number, name, email, course, and which board has been rented, as required by the customer. The boxes the devices are held inside must be uniquely identifiable according to the department, so each box must be scanned into the database before a device is taken. This is to prevent the theft of a device by any student and allows the customer to know which is taken. For the same reason, the machine shall have a card reader to ID every student. This way no student can fake the number, even if other information was incorrect.

For the entire machine to function after a reset and to remember information for the customer, the machine is required to have a form of nonvolatile memory such as MicroSD or an actual separate drive. The machine must have a series of LED (light emitting diode) indicators so the student knows which drawer and compartment to access when

retrieving the board. Solenoid Locks shall be installed into the drawers and compartments so no single person can easily break through to the devices when the machine is unsupervised. The current plan is for a drawer and compartment to hold for several minutes to allow enough time for a worker to notice the attempt.

The following subsections provide detail on each of the previous requirements and how each shall be completed according to the customer.

### II. BACKGROUND

One of the most important subsections that will be mentioned is control for the vending machine. For controlling the physical aspects, a programmable logic controller (or PLC) will be used. A PLC is most commonly used in industry for controlling mechanical systems and applications. Some examples of systems typically controlled by PLCs are road traffic signals, automatic car washes, and automatic doors [1]. These applications tie into some of the applications in the vending machine such as the LED indication system, the process of selecting boards, and the locking of the doors and drawers. Because these systems need to have some sort of control software, a PLC is a likely candidate. In addition, because there are not a lot of systems that need to be controlled, a smaller, less power-intensive PLC will most likely be used.

Another subsection that needs to have clarification is the database. The database is where student information, such as T-Number, will be stored and sent to the ECE office. As stated in the introduction, an SQL database will be used. SQL is a query language that can facilitate communication to and from a database, as it can retrieve, insert, update, and delete information in a database. SQL can also create new databases and tables within a database [2]. The SQL language will be crucial to implementing the vending machine because of the need for a database.

Finally, as stated in the introduction, an MCU will be used in order to program the SQL database. An MCU is simply "an electronic device with a microprocessor as

its central processing unit (CPU),” [3]. The microprocessor is what will perform the digital functioning of the MCU, as the microprocessor is what contains the circuitry of the MCU. In tandem with a PLC controlling the hardware, the MCU will control the software side of the vending machine. Both are needed in order for the vending machine to properly work.

### III. ETHICAL CONSIDERATIONS

During the process of designing this vending machine, every scenario that can occur must be taken into consideration. The vending machine will be plugged into the wall for its power supply. The supply voltage will be 120VAC before it's sent through the AC/DC converter. It must be certain that the voltage is properly stepped down and converted to DC. The desired voltage is roughly 5V DC; given that “30 volts is generally considered to be a conservative threshold value for dangerous voltage,” a person could be severely injured in the event of incorrect conversion [4]. In order to counteract this, there will be a system in place to detect if there's a spike in voltage or current in the AC/DC converter and trip the power supply. This system will most likely be a ground-fault circuit interrupter (GFCI). Having this within the power cord for the vending machine will comply with the National Electric Code (NEC) standard NEC 422.51, which requires vending machines that are powered by cord-and-plug to have a GFCI located near the wall plug [5].

In addition, security must be put in place to prevent student data from being compromised. One security measure is connecting the vending machine's database to the ECE office's computer by ethernet. This is because “An Ethernet connection is much more secure than a Wi-Fi connection. Data on an Ethernet network can only be accessed by physically attaching a device to the network, while data on a Wi-Fi network travel[s] through the air and can be more easily intercepted,” [6]. An Ethernet connection will make it more difficult to steal student information compared to a Wi-Fi connection since data can only be stolen by attaching a device to either the vending machine or the ECE office's computers. In using Ethernet as a form of communication, the connection must follow the Institute of Electrical and Electronics Engineers (IEEE) standard IEEE 802.3-2018, which gives a selection of speeds at which an Ethernet connection must work [7].

To work with the Ethernet connection, a form of encryption will be used on the student information before it's sent out. One option for this is using a cipher of some sort. A cipher is a phrase or string of words that information is shifted by in the alphabet. This will make the received information look jumbled, though it will be deciphered upon retrieval.

Finally, a scenario that must be considered is the stealing of a device from the vending machine. Given the chance that the faculty in the ECE office may step out of the office

for a few minutes, there is a chance that someone could attempt to break into the vending machine to steal the devices within. To help prevent this, the vending machine will have locks on both the drawers and the lids of each device. There will also be a sensor system in place to detect if a box is in its compartment. While this will be mainly used for the SQL database, it can be given the purpose of detecting if a device is removed without approval.

### IV. BLOCK DIAGRAM

#### A. Raspberry Pi

To meet the requirement of an MCU to hold the data of the system, a Raspberry Pi will be included to support a database for student information and allow the transmission to the customer. A Raspberry Pi is a small computer that can communicate with any input and output gear, such as a monitor, a computer, a mouse, or a keyboard, turning the setup into a packed PC at a reasonable price.

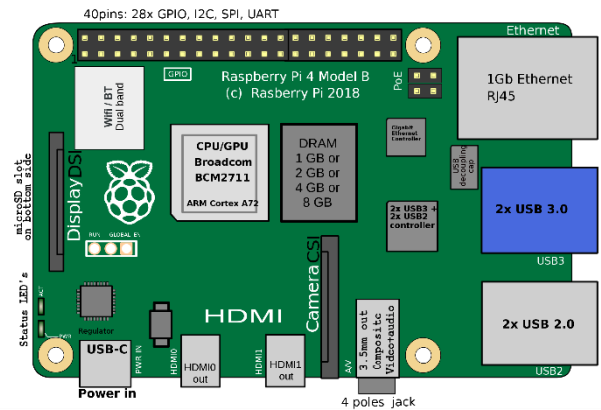


Figure 1: Layout of Raspberry Pi 4 Model B [8]

The main characteristics of this product include a powerful 64-bit quad-core processor, dual-display support at resolutions up to 4K via two micro-HDMI (High Definition Multi-media Interface) ports, hardware video decoding at up to 4Kp60, a maximum of 8GB of RAM(Random Access Memory), dual-band 2.4/5.0 GHz wireless LAN (Local Area Network), Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE (Power over Ethernet) capability (via a separate PoE HAT add-on) [9].

The Raspberry Pi will be mainly used for the following functions:

#### 1) SQL Database

##### a. Inventory

The database will be used to keep a record of the inventory inside the machine and will be able to tell the customer whether a device is loaded or unloaded from a sensor in the PLC system. If loaded, the system will check whether the box is scanned in by the barcode scanner. If unloaded, the system will check whether the box is not scanned. All information will then be recorded and saved in the inventory section of the database.

##### b. Student Information

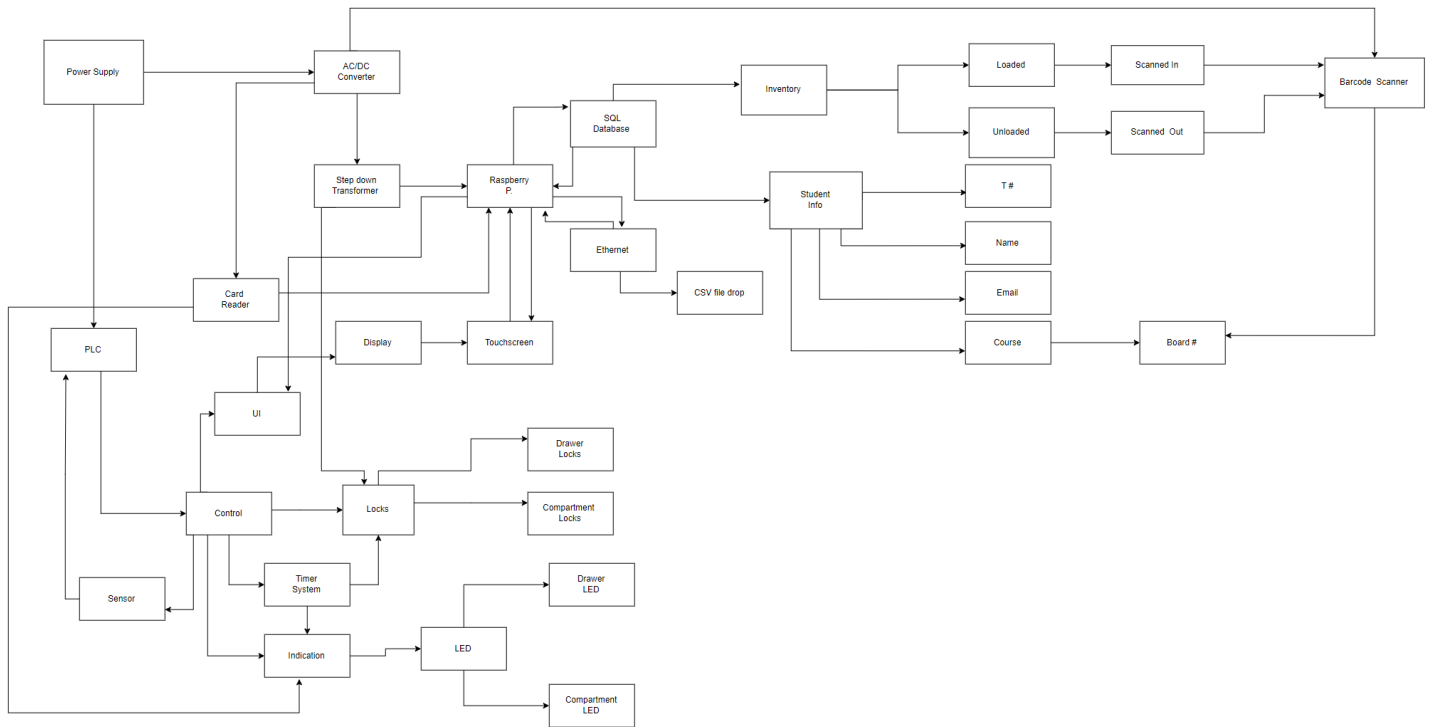


Figure 2: Block Diagram

The database will also be used to keep a record of the students who have rented devices for classes and will also be able to send the data to the customer through Ethernet. Under the student portion of the database, the T number will be recorded from the card reader connected to the MCU. The name and email of the student will be taken in by a user interface. A course section will then be chosen from a list of courses held by the database. Once a board is chosen, the barcode will be read by the scanner and logged for use by the customer.

## 2) Ethernet

### a. File Drop

The ethernet cord shall be used to send and receive data to and from the customer. If the customer wants to see the database and who has taken items, they can request the file and it will be transmitted. The file will likely be a CSV from Excel that will feed from and to the database. The ethernet cable can be directly connected to Pi and user PC using ethernet connector which uses RJ45 connector, and with the right steps of static IP configuration one can start transferring data from the Pi.

Input: Encoded message to the database

Output: Message signal to the connected device

## 3) UI (User Interface)

The user interface will be connected to the MCU and will allow the user to input their name, email, and which class(s) he or she needs a device for. The information is also relayed through the PLC system.

### a. LCD (Liquid Crystal Display)

In order for the student to select the needed board an LCD display would be used through which student would input their name, email address and after verifying the information they will choose the needed board with the help of touch screen LCD. The needed LCD would most likely be from the same company of our MCU i.e. Raspberry Pi as it would be most compatible with our MCU. An adapter board that converts power and signal is used to connect the 800 by 480 monitor. There are just two connections needed to the Pi: a ribbon cable connecting to the DSI connector included on every Raspberry Pi, and power coming from the GPIO port. The most recent Raspbian OS will have touchscreen drivers so that users can operate their devices completely without a hardware keyboard or mouse and with 10-finger touch capability and an on-screen keyboard [10].



Figure 3: LCD Screen with Connector and MCU [11]

Input: Message Signal to Raspberry Pi

Output: Raspberry Pi signaling to PLC

#### 4) Card Reader

The card reader shall receive a signal from an ID card issued to the student by the college. When the signal is received, the device will send the data to the database through the MCU. The Reader will have an indicator light for a correctly scanned card to notify the student that he/she is good to proceed.

Input: Information from Eagle Card

Output: Create Data and signal to Raspberry Pi

### B. PLC

In order to give the vending machine's hardware reactive functionality, a PLC will be implemented along with its necessary sensors.

#### 1. Control System

##### a) User Interface (UI)

The PLC will control the hardware behind the UI used for students to check out their boards. The UI will allow students to enter their name and email. The UI will also interact with our microcomputer in order to send the student's information to the database. Functionality will be tested by entering a generic name along with team member's email. Once this is done, the database will be checked for the entered information.

Input: Powered by the MCU, controlled by the PLC. Student's name and email will be entered.

Output: Student information to the MCU to send to the database.

#### b) Locks

The locking system will be solenoid coils energized by the PLC. The PLC will run the student's course number and board needed through comparison functions to find where it is equal to a board number that isn't checked out. Once it finds an equality, the corresponding locks will become un-energized so the student can grab the board. The functionality will be tested by running a test line in the PLC to see if a lock's tag correctly updates.

Input: Powered by the vending machine, energized by the PLC.

Output: Locking and unlocking the drawers and compartments containing the devices.

##### i) Drawer Locks

The first line of defense for the stored objects are the locks for the drawers. Since these are easily accessible, they will require stronger locks than the internal locks. They will have to resist forceful entry and external interference. These locks will return to standby (closed) after the item has been removed and the drawer is shut.

##### ii) Compartment Locks

These locks prevent the opening of the separate compartments inside of the drawer. Since they are harder to access and in a more compact environment, the locks will not be as strong as the ones holding the drawers shut. These locks will return to standby (closed) after the item has been removed and the compartment is closed.

#### c) Indicator

The vending machine will have an indication system to guide the student to the correct drawer and compartment. When the PLC finds the correct board needed by the student, it will run the board's tag through compare commands until it finds the corresponding indicator tags. Once the tags are found, they will be energized and un-energized on a timed system.

Input: Voltage from machine, energized from PLC, set to flash at certain interval with timer system.

Output: Drawer and compartment indicators will flash to show where the device is located.

##### i) LEDs

To assist the user in identifying the location of their required device, there will be LED indicators on both the drawers and

separate compartments. There is a total of 1 LED for each drawer, and 1 LED for each compartment inside of the drawer. When the user is given the location of their rented device, the LED will blink on the drawer that has been unlocked, as will the LED of the specified compartment. LEDs will return to standby after the item has been removed and drawer has been shut.

#### d) Timer System

The PLC will run the timer system used in tandem with the lock and indication systems. This system will be used to hold the solenoid coils as unlocked for a reasonable duration in order for the student to grab their device (roughly 15-20 seconds). Once the time has elapsed, the coils will become energized and will lock once the drawer and compartment are closed. The timer system will also set the period of flashing for the indication system. Once the time for the coils has elapsed, the indicators will also stop flashing.

Input: Total duration from PLC, tag update from PLC.

Output: Solenoid coils will be unlocked for a given duration. During this duration, the indicators will flash to show where the device is located.

#### e) Sensors

We need sensors to see whether which compartments have a device in them so as to see whether they need to be restocked if empty or to be distributed if there is a device. If there are not sensors than the machine would not know which compartment has a device or not. There are several options as for what kind of sensors we could use, but we are mainly considering two of them.

The first sensor we are considering is a visual Photo Eye light sensor. This sensor emits an infrared signal and captures the signal if reflected back to it. If a device is in between the Photo Eye and the mirror across from it than the Photo Eye will send a signal that the compartment has a device in it. The second option we have considered is using a scale to measure the weight of the bottom of the compartment. If the scale measures no weight than it will send a signal that there is not device in that compartment.

The biggest factor into which sensor we will choose is the price; Whichever way for sensing is cheaper is probably the route we will take. One possible problem is that the Photo Eye sensors might take up too much room in the compartments. Also, the scales could possibly be impractical if

they need to be recalibrated after being implemented from some extraneous circumstance like if the vending machine is moved.

#### C. Power Supply

A power cord will come from the wall outlet to hook up to the vending machine. This will supply power to the PLC, if it takes AC current, and to the AC/DC Converter

##### a) AC/DC Converter

For the Raspberry Pi MCU to be powered the incoming power must be converted to DC and then stepped down with a step-down transformer. The Card Reader and Barcode must be powered with DC as well; whether the voltage needs to be stepped down or not is tentative as of now. Also, the AC/DC converter will also convert the power from the supply to power the drawer and compartment solenoid locks to disable.

#### D. Barcode Scanner

To register the individual devices to the machine and properly keep track of the current ownership of the device, a barcode scanner will be installed. When loading the devices, the user will first have to scan their barcode, registering them to the indicated compartment. This will tie the device's ID to the compartment's location. The next board cannot be loaded until the previous one has been registered and locked. This will allow the database to then tie the rented device to the student, allowing us to keep track of its possession.

Input: ID of the device.

Output: Registering the location of said device.

#### V. TIMELINE

The attached Gantt chart displays the task to be completed over the course of the project. Each phase contains the label of the tasks, the time allocated, persons assigned, and dependencies of other task. Phase 1 is comprised of the design process. Phase 2, pre-construction, is the time between approval and holiday break. This will be used as the prep time before our official construction phase, completing the work needed to be completed before working on the final product. Phase 3, the construction phase, is when most of the work will be done and is separated into 3 sub sections: Programming, Integration, and Physical Build. The programming will be primarily handled by Dillon Williams and Nidhay Patel, while the integration will be overseen by Austin Sigg, Ryan Reed, and Michel Turpeau. The final construction phase will be a collaboration between the ECE team and ME team. Phase 4, finalization, will primarily be testing and adjustments, ending with the delivery of the final product.

(The chart is attached on page 6)

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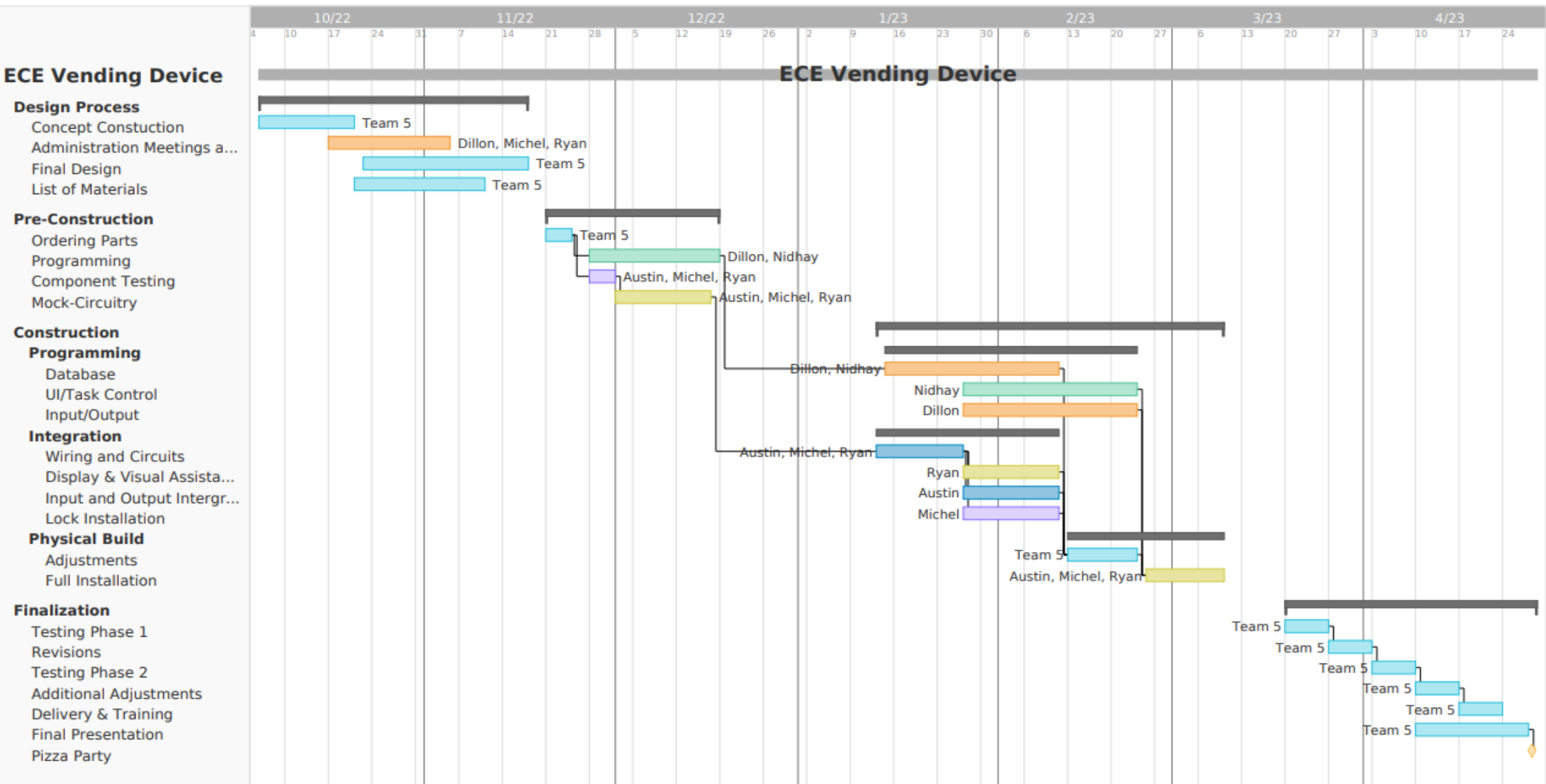


Figure G - Timeline