DESIGN PROPOSAL

THE MULTIPURPOSE STORAGE SYSTEM [1]

AER201: Engineering Design
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1. EXECUTIVE SUMMARY

1.1 PROBLEM

Existing self-storage systems are difficult to customize to the personal needs of a user. Most existing solutions tend to be very homogenous in terms of the amount of storage space they provide, are intended for use in a fixed configuration and due to their non-automated nature, can be difficult to administer.

1.2 SOLUTION

The proposed solution is an electronic modular storage system that allows compartments of different sizes to be assembled in random configurations, such that users can lock and unlock their assigned modules from an electronic interface. The system will be controlled by a microcontroller, which will confer advantages over traditional manual systems including flexibility in module assignment, and improved security since access logs can be created to record system activity.

1.3 FUNDING REQUIREMENTS

The projected development cost for the prototype, including experimentation and spare parts is $1045 while the final material cost of the prototype itself is $192.64. These funds will be raised from the income of team members, who are certain the prototype can be completed within the cited amount.

1.4 ORGANIZATION

All members are responsible for the conception and final integration of the prototype, but the task of implementing the proposed solution will be subdivided into three components, each spearheaded by a team member. Duluxan Sritharan will be responsible for software development and integration between the microcontroller and the user interface (Microcontroller member), Fangzhou Su will design circuits for the pushbuttons and actuators (Circuits member), and David Wang will be responsible for the design of the storage modules and the placement of powered mechanisms (Electromechanical member)

2. PROBLEM FORMULATION

2.1 STATEMENT OF NEED

The self-storage industry is booming in North America, with annual sales in excess of $20 billion US [2]. In fact, the average US household rents 20 square feet of storage space [2], in addition to free storage in the form of mailboxes, lockers, and garage organizers. Given the prevalence of self-storage, and the diverse array of uses that exist for it, there is a clear demand for storage modules that are secure, easy to use, and specialized according to the nature of the user's need. Any such functional system would be a boon for consumers and industry alike.

2.2 GOALS AND OBJECTIVES

The purpose of this proposal is to outline a concept for an automated storage system consisting of different-sized storage modules, and to present a plan for the manufacture of a proof-of-concept prototype. The goal is to manufacture five storage modules successfully, such that the configurable, modular, and automated nature of the device is illustrated. The functionality of this system includes set-up and interaction through an LCD/keypad interface. More specifically, the prototype must achieve several physical, functional and security objectives.

The prototype must contain 2 small modules, 2 medium modules and 1 large module with nominal interior dimensions (H mm x W mm x D mm) of 200x250x200, 350x300x200 and 500x400x200 respectively within a 10mm tolerance for each dimension. The outer dimensions for all the modules must not exceed 700mm (H) x 600mm (W) x 400mm (D). Each module must not weigh more 2 kg, and must be able to support another 1 kg. The modules should be designed such that they can be easily and quickly configured and assembled. The system must be powered by a standard AC 110 V-60 Hz- 3 pin outlet. In the case of a power outage, a back-up rechargeable DC power supply must ensure uninterrupted operation. Lastly, the total material cost for the prototype must not exceed $200 CDN before taxes.

The system must be controlled by an on-board processor, which facilitates opening/closing and locking/unlocking the storage modules. The system should be able to automatically close module doors 15 seconds after opening, although the user should be able to close the door before this period, or keep it open after, if he/she desires. Once closed, the door must lock within 3 seconds. The operator must be able to interact with the system using an LCD/keypad interface that allows various functionalities to be performed according to the operator's status as administrator, user or guest, including gaining access to specific storage modules.

In particular, the administrator must be able to regulate all accounts by setting validity periods, monitoring system activity via the weekly logs and having the capability to access all modules. It should be difficult to violate the integrity of the system from the front faces of the modules (i.e. disassemble the modules, tamper with electronic components or gain unauthorized entry).

3. SURVEY

3.1 IDEA SURVEY

Existing ideas for both individual components and the entire system were surveyed for relevance to the RFP. For the door opening/closing mechanism, motor-driven devices, hydraulic arms, electronic doors such as those used for wheelchair accessible doors, obstructive devices such as door stops, and even pulling arms such as those on pedal-operated trash cans were considered. Relevant locking mechanisms include deadbolts, physical jigs and magnetic adhesion. Existing solutions for maintaining the rigidity of assembled systems include both material solutions (e.g Velcro), structural forms (e.g. jigsaw molds), and physical restraints (e.g. cord bike locks). Inspiration for modularity was drawn from IKEA furniture, which is always designed to work both *in situ* and as a part of a larger system.

Mailbox rooms in apartment complexes are very similar to the required product, albeit for the lack of automation. Mailboxes of different sizes can be inserted and locked in place from a back room by the superintendent, while users can only access their assigned compartments from the front. Locker rooms in swimming pools also have similar operational characteristics since they are comprised of lockers of different sizes. Here, instead of an automated interface, the user signs in with the clerk, who gives him/her a key to access a certain module. These systems are relevant since the product outlined in this proposal is intended to be used in settings like these.

3.2 MARKET SURVEY

Automated, modular storage systems are not readily available for consumer use. While electronic safes are prevalent in both residential and commercial applications, they are unsuitable for this particular problem, because they are designed to be standalone devices. Low-cost modular storage systems such as tool organizers or communal mailboxes still rely on keys, combination locks or padlocks, requiring the user to manually operate each storage compartment. Warehouse storage lockers do exist but are intended mostly for industrial applications with capacities exceeding levels appropriate for everyday use in applications like mailboxes. One product that is similar to the one required is the Hanel Multi-Space produced by Industore, which has “variable container widths, different payload capacities” and the ability to add modules later as required [3]. However, this product not only stores items but also transports them out of reach to minimize floor space, which is not desired in this case.

3.3 LITERATURE SURVEY

There is little research or documentation available. Most scientific articles pertain to AS/RS (automatic storage and retrieval systems) that are used in manufacturing to transport items to different levels of a factory. The U.S. Patent Office has a patent (20080208389) for “an automated storage system comprising: a) a plurality of storage locations; b) at least one access location; c) at least one storage container provided on at least one storage location; d) a control system and at least one user interface, the control system further comprising a retrieval mode and a storage mode” [4]. While the overall system configuration is similar to what is required by the RFP, it is intended for loading/unloading modules directly onto vehicles.

4. CONCEPTUALIZATION

4.1 Decision-Making Protocol

All decisions regarding the proposal including specific subsystem decisions were made as a team. When the decision influenced all subsystems, we aimed for consensus but in the case of a majority without consensus, we expected constructive participation on a going-forward basis from the third member. In decisions that were particularly pertinent to a specific subsystem, or when a certain member had more expertise, the other members contributed feedback but ultimately deferred to the judgment of the expert member. In cases where all three members had different opinions or there wasn’t enough immediate information to make a decision, it was expected that each member would perform individual research, so that a decision could be made by the next meeting scheduled within 2 days. In all considerations, the value of practicality was emphasized and simple designs that could be implemented easily were always preferred over more impressive but complicated designs.

There was no one set of criteria used for decision-making, but rather criteria were derived for each component based on the most relevant set of parameters. Candidate solutions were then evaluated according to these criteria and the best solution was chosen. For the following pages in this section, candidate designs that were considered for each major component are noted and evaluated based on a relevant set of criteria, which are listed from most important to least important

4.2 Design Considerations for Electromechanical Subsystem

4.2.1 Exterior Module Dimensions

Ranked Criteria: Configurability, Material Cost, Bulkiness

<table>
<tr><th rowspan="2" colspan="2">Candidate</th><th colspan="4">Dimensions (mm)</th><th rowspan="2">Evaluation</th></tr>
<tr><th>Size</th><th>H</th><th>W</th><th>D</th></tr>
<tr><td rowspan="3">A.</td><td rowspan="3">Uniform</td><td>S</td><td>600</td><td>600</td><td>300</td><td rowspan="3">Allows full re-configurability since all modules are essentially equivalent from an external point of view but results in an unnecessarily oversized container</td></tr>
<tr><td>M</td><td>600</td><td>600</td><td>300</td></tr>
<tr><td>L</td><td>600</td><td>600</td><td>300</td></tr>
<tr><td rowspan="3">B.</td><td rowspan="3">Constant Periphery</td><td>S</td><td>300</td><td>350</td><td>300</td><td rowspan="3">Intuitive since all there is a constant difference of 10 cm between inner and outer walls for all modules but is difficult to configure without gaps in the middle.</td></tr>
<tr><td>M</td><td>450</td><td>400</td><td>300</td></tr>
<tr><td>L</td><td>600</td><td>500</td><td>300</td></tr>
<tr><td rowspan="3">C.</td><td rowspan="3">1:2:3 Height Ratio</td><td>S</td><td>225</td><td>500</td><td>300</td><td rowspan="3">Ensures full horizontal configurability (same width for all modules) and reasonable vertical modularity, but provides inadequate vertical space to place mechanisms in the small module.</td></tr>
<tr><td>M</td><td>450</td><td>500</td><td>300</td></tr>
<tr><td>L</td><td>675</td><td>500</td><td>300</td></tr>
<tr><td rowspan="3">D.</td><td rowspan="3">2:3:4 Height Ratio</td><td>S</td><td>300</td><td>500</td><td>300</td><td rowspan="3">Allows enough working space for any required mechanisms, allows full horizontal configurability and satisfactory vertical configurability.</td></tr>
<tr><td>M</td><td>450</td><td>500</td><td>300</td></tr>
<tr><td>L</td><td>600</td><td>500</td><td>300</td></tr>
</table>

4.2.2 Module Design

Ranked Criteria: Strength, Simplicity, Cost

Candidate	Description	Evaluation
A. Slide-Out Drawer	A compartment with required inner dimensions would slide out of a case, much like a drawer of a filing cabinet.	Rejected because of the perceived weight, required material and complexity of actuators required to move the drawer.
B. Dual Shell with Frame	Two embedded boxes made of solid walls supported by a lattice frame with upright door	Rejected because the weight constraint of 2 kg may have been violated if all walls were made of wood or metal. In addition, the frame for (B) would have been more time consuming to create.
C. Dual Shell with Panels	Thin "hardboard" plywood for inner shell and cardboard outer shell held together by right-angle brackets with upright door	Ideal since the thin walls and the sparse use of metal make it both lighter and quicker to fabricate than (B). The cardboard wall is cost-effective, while the inner hardboard core is strong enough to support the required load.

4.2.3 Module Attachment Mechanism

Ranked Criteria: Manufacturability, Configurability

Candidate	Description	Evaluation
A. Physical Jig	The modules can be connected by virtue of their interlocking outer shape	Rejected because of the difficulty of manufacturing interlocking outer shells.
B. Bolt and Lock	Modules are attached at the back by attaching a screw between them	While robust, it has security issues since the modules have the potential to be pried apart from the front where this is no connection.
C. Velcro	Straps are placed around the periphery and modules are stuck together	Most satisfactory since the continuous adhesion surface does not limit configurability. Since all the modules have the same depth, attaching the Velcro at a fixed depth from the back during fabrication makes attachment very simple during operation.

4.2.4 *Locking Mechanism*

Ranked Criteria: Manufacturability, Complexity

Candidate		Description	Evaluation
A.	Motorized Lock	A motor turns a rotating latch that catches on the frame and prevents the door from opening.	Rejected because of the precision required in manufacturing so that all mechanical parts operate reliably.
B.	Solenoid Driven Bidirectional Deadbolt	A solenoid is used lifts a deadbolt when opening and closing the door	Attractive due to the simple nature of the mechanism – deadbolts are easy to make and provide adequate locking.
C.	Unidirectional Solenoid Driven Deadbolt	A solenoid is used to lift a deadbolt when opening the door, and rides up a physical jig into a slot when closing the door	Provides the same functionality as (B) without having to power the solenoid twice. More reliable since the simple curvature of the deadbolt housing case is enough to push it in place when the door is closed.

4.2.5 *Door Mechanism*

Ranked Criteria: Cost, Manufacturability, Complexity, Power Consumption

Candidate		Description	Evaluation
A.	Linear Motor	A linear motor placed at an angle outside the inner compartment would open and close the door.	Most obvious mechanism but cannot apply a uniform torque continuously over the entire opening/closing operation.
B.	Rotary Motor and Gear	A rotary motor connected to a gear in the hinge would open and close the door.	Rejected because of the high cost of gears, required customization of gear ratio setup for each module and space requirements.
C.	Spring Loaded Door	Contraction of springs pull door closed after release.	Allows the door to close automatically without the use of electricity but requires secondary mechanism to keep door open.
D.	Ratchet and Pawl	A toothed ratchet located above the hinge prevents the door from closing unless pawl is released	Rejected because of the difficultly in manufacturing precise parts, and the unavailability of off-the-shelf ratchets.
E.	Solenoid Jam	A solenoid drives a rod between the door and frame when activated keeping the door ajar.	Very simple way of keeping the door open but solenoid lifespan could be very low if it needs to be activated for 20 seconds at a time to satisfy RFP constraints.
F.	Two-State Solenoid Jam	Like (A) but power is required to change rod's position but not to maintain it.	Ideal because of its simple premise. Unlike (F) impulse current is only required for triggering a change in state, so power only needs to supplied in smaller intervals thereby reducing component failure rate.

4.3 Design Considerations for Circuit Subsystem

4.3.1 Solenoid Signal Circuit

Ranked Criteria: Complexity, Implementation Time

Candidate	Description	Evaluation
A. 10 Output Pins	1-hot pin assignment from PIC for each solenoid in the system (5 modules x 2 solenoids per module)	Requires the simplest circuit design. But was rejected since it took up too many pins from the PIC and couldn't fit in a single port.
B. 7 Output Pins	1-hot pin assignment for each of five modules and 1-hot pin assignment for each of two mechanisms	Requires a simple decoder circuit and a lower number of output pins from the PIC. The decoder circuit also as a buffer circuit for the PIC.
C. 4 Output Pins	Encoded 4-pin assignment for boxes and action.	Requires fewest output pins from the PIC, but was rejected because coding the assignment as well as decoding the signals adds complexity to the design

4.3.2 Solenoid Power Circuit

Ranked Criteria: Cost, Safety, Complexity

Candidate	Description	Evaluation
A. Transistor Controlled	High powered Darlington transistors drive solenoids directly	Allows for the simplest circuit design, but it requires high power transistors, as well as heat sinks for them. It was rejected for the cost of the heat sinks.
B. Transistor and Relay Controlled	Low powered signal transistor drive a relay to power the solenoids	More complex circuit design than (A) but does not require heat sinks; use of relays isolate sensitive circuitry (PIC, logic gates) from solenoid circuitry.
C. Driver Board	Using the built-in functionality of the driver board	Rejected because it costs too much, and the difficulty in expanding its 3-actuator control capacity to 10.

4.3.3 Voltage for Door Jamming Solenoids (5V Rating)

Ranked Criteria: Safety, Strength

Candidate	Evaluation
A. 5 V	Rejected because experimentation revealed that the solenoids do not exert enough force to push the 2-stage actuators to its upright position.
B. 12 V	Accepted because the voltage is only applied for short period of time (maximum 5 seconds), and the solenoids are capable of exerting enough force at this voltage. Consultation with TA revealed safety risks and component failure rates are still minimal.

4.3.4 Voltage for Locking Solenoids (24 V Rating)

Ranked Criteria: Safety, Strength, Complexity

Candidate	Evaluation
A. 5 V	Rejected because the solenoids did not work under 5V during experiments.
B. 12 V	Accepted because the solenoids are functional at this level, and no conversion is required to step up the power.
C. 24 V	Rejected because it requires additional circuitry to raise the voltage to 24V and this level of strength is not required for the application for which these solenoids are intended.

4.3.5 Operator's Door Closing Mechanism

Ranked Criteria: Security, Functionality, Complexity

Candidate	Description	Evaluation
A. Keypad Interaction	User pushes button on keypad to close door.	Rejected because it requires the user to leave module unsupervised and navigate to the keypad to close the doors.
B. Parallel Switch with Solenoid Power Control Mechanism	Switches on the door are connected in parallel with the relays or transistor (depending on decision in 4.3.2.1) to unjam the door	Rejected because the PIC will not know if the user chooses to close the door prematurely and may jam the door again after 15 seconds.
C. Active-High Switch	Switches on door are connected to input pins on PIC (active high)	Lets the PIC know that the user chose to close the door. Rejected because the PIC might have floating voltages when the switch is not closed.
D. Active-Low Switch	Switches on door are connected to input pins on PIC (active low)	Accepted because it offers same benefits as (C) without the floating voltage issue.

4.4 Design Considerations for Microcontroller Subsystem

4.4.1 Choice of Microcontroller Board

Ranked Criteria: Cost, Timeline, Functionality, Usability

Candidate	Description	Evaluation
A. PIC Proto64 Board	Basic board that permits clear signal transmission but has no debugger/programmer	Rejected because of the difficulty in programming the PIC, and setting up connections with the LCD and keypad in a tight timeline.
B. PIC Development Board	Built-in programmer with some peripherals but no runtime debugger	Rejected because LCD and keypad still have to be wired, and it is difficult to integrate the system without a debugger.
C. PIC DevBugger	Built-in keypad, LCD, programmer and debugger, and uses chips on socket.	While expensive, it is versatile and provides a wide range of built-in functionalities which would otherwise be time-consuming to implement.

5. SPECIFICATIONS

5.1 SYSTEM OVERVIEW

The diagram below illustrates the overall system configuration of the proposed design. Each storage box has 2 solenoids and one close switch. More detailed circuit schematics can be found in Appendix C.

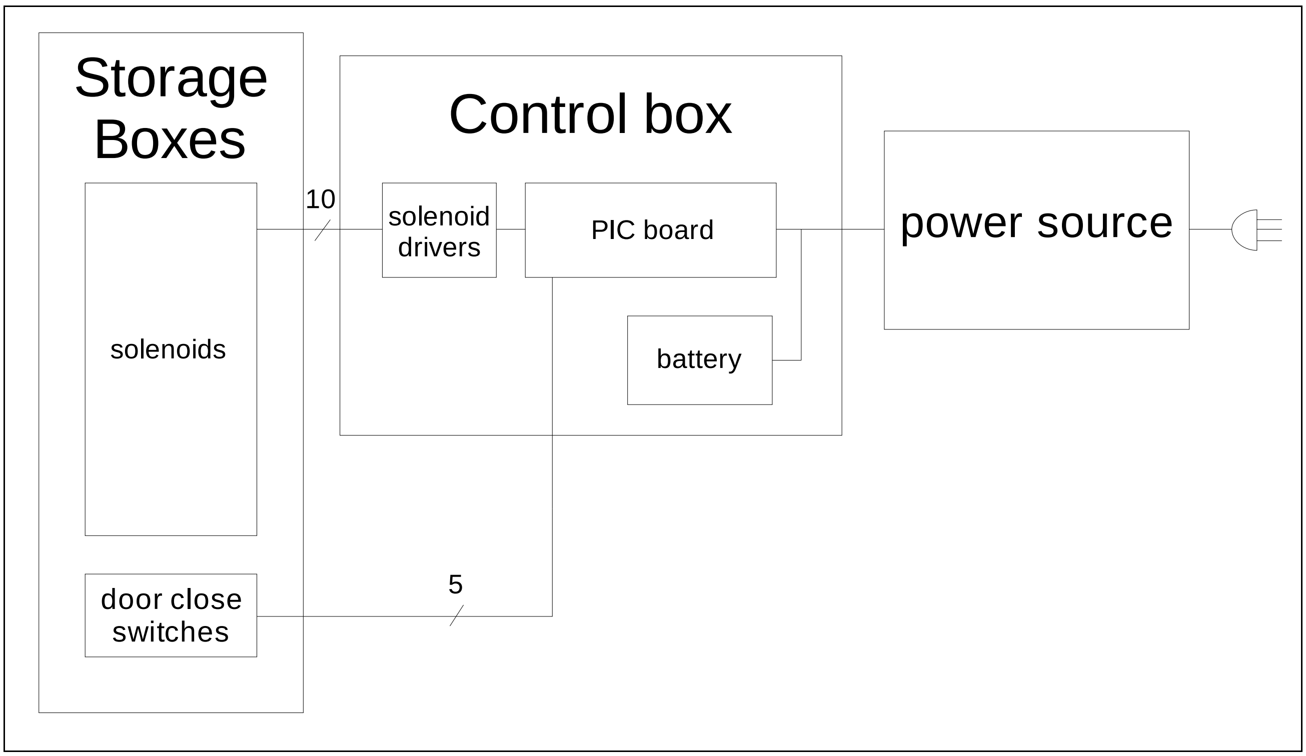


Figure 1: Basic system overview of prototype.

5.2 FUNCTIONAL DESCRIPTION

5.2.1 Operator Interface

The operator will interact with the system using a 4x4 keypad and a 16x2 LCD screen. Initially, the operator will be prompted for his account ID and password. Based on correct input for these two fields, he/she will be identified as an administrator, user or guest and be given specific functionalities.

As an administrator, he/she can electronically configure the system, by specifying the size and providing an alphanumeric code for each module based on which port in a central hub each module is connected to. The operator can also access account information, allowing him/her to add accounts by supplying a username and password, modify accounts by changing passwords and deciding which modules an account has access to, and deactivate certain accounts for a given amount of time. An administrator will also be able to lock or unlock any module, and be able to retrieve weekly logs of user/guest and module activity.

If the operator is a typical user, he/she will be able to change passwords and gain access to any modules to which he/she is assigned. In addition, a user has the option of creating a guest account, which has access to a certain subset of the user's modules, by specifying a guest password and validity period.

Finally, a guest will have the option of opening any module, for which a user has granted him/her authorization.

5.2.2 Mechanical Operation

The mechanical operation of the system is controlled by a locking mechanism and an opening/closing mechanism. These mechanisms are only active when the operator wishes to gain access to a specific storage module.

Once the operator has provided the proper instructions to the user interface, the door to the selected module will unlock for three seconds, during which the user is free to open the door manually. If the door is not opened within this time period, the door locks again.

If the door is opened, a door jamming mechanism will keep the door ajar for 15 seconds during which the operator may store or retrieve items from the compartment. After 15 seconds, the door jamming mechanism will be deactivated, leaving the door free to close. The user may continue to use the module after the 15 seconds are up, but he/she must now manually hold the door open. Once the user releases the door, the door will automatically close and lock.

If the user chooses, he/she can close the door before the allotted 15 seconds expires by pressing a button on the door which releases the jam, and allows the door to close ahead of time.

5.3 Electromechanical Subsystem

5.3.1 Physical Characteristics

The inner dimensions of the small, medium and large modules (H mm x W mm x D mm) will be 200x250x200, 350x300x200 and 500x400x200 respectively within a 10mm tolerance for each dimension. The outer dimensions of the small, medium and large modules (H mm x W mm x D mm) will be 300x500x250, 450x500x250 and 600x500x300 respectively, with a 5mm tolerance for each dimension. These outer dimensions guarantee that the modules can be assembled in various configurations without having unsightly gaps that reduce the modularity of the system. See Figure 2 for plan and front views of the modules.

One box will be constructed for the inner compartment and another for the outer compartment of each module. On the front face, a plate will be fashioned so as to hide the space between the two compartments from the operator. The door for each module will be a typical vertical hinge design, with the door having the same width as the inner compartment and the same height as the outer compartment. See Figure 3 for a detailed design of the small module.

The outer walls for the modules will be constructed out of cardboard, because it is cheap, and allows the concept to be effectively conveyed. The inner walls and the door will be made of "hardboard" panels, a very thin, light, but sturdy type of plywood. This allows for the prototype to withstand both the 1 kg load, and the loads from supporting other storage modules, without being overweight itself. The walls will be attached using glue and reinforced with well-spaced L-brackets. If this concept were to be mass-produced, stronger materials should definitely be considered such as sheet metal according to the nature of the application.

The modules will also have strips of Velcro tape around their periphery at a constant depth. Since all modules have the same depth, this allows the modules to be attached together easily. Velcro allows the system to be assembled quickly without the need for extra parts. Due to its continuous adhesion surface, module configuration truly can be arbitrary.

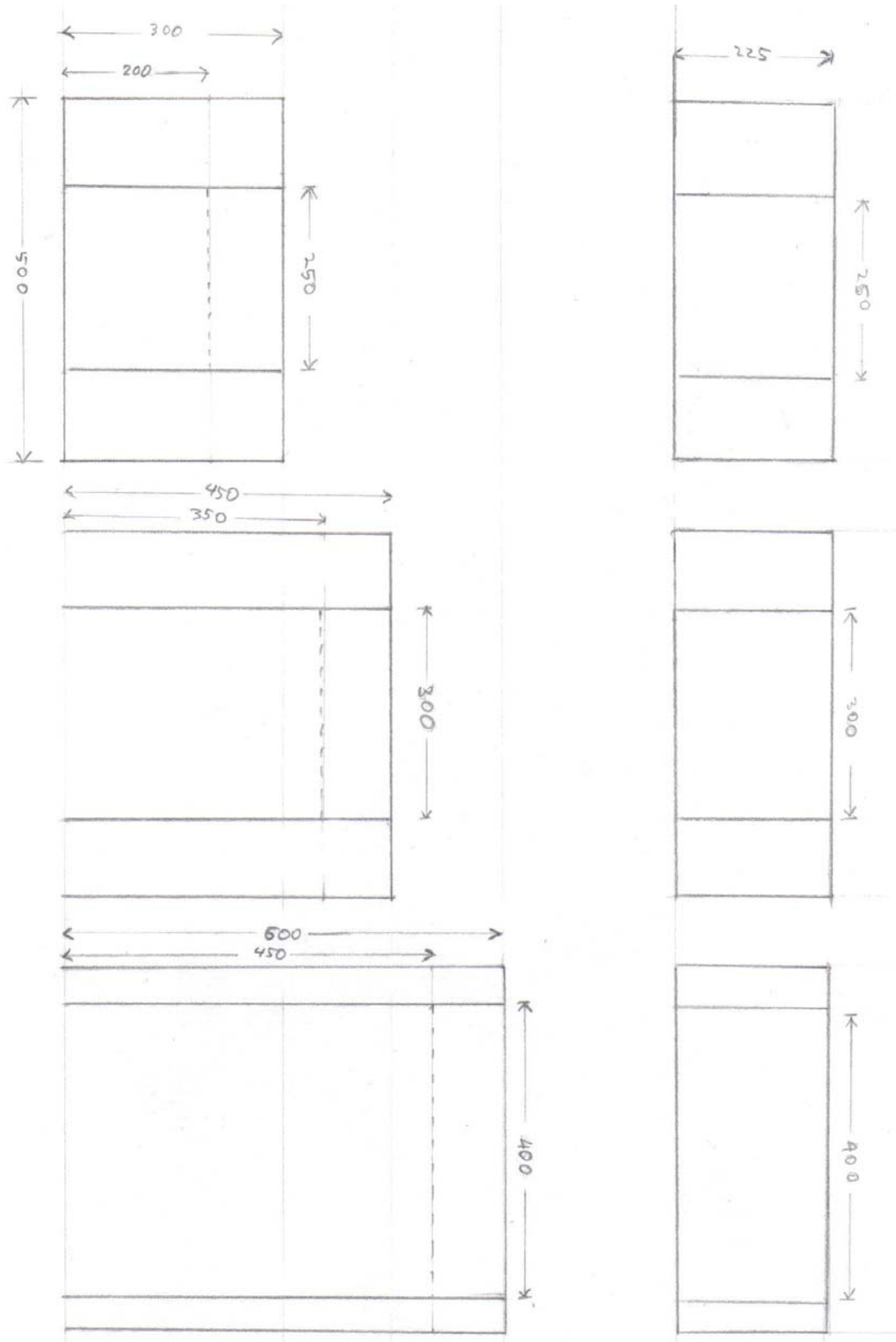


Figure 2: *Front (left) and plan (right) views of small (top), medium and large (bottom) modules. Scale 1:10*

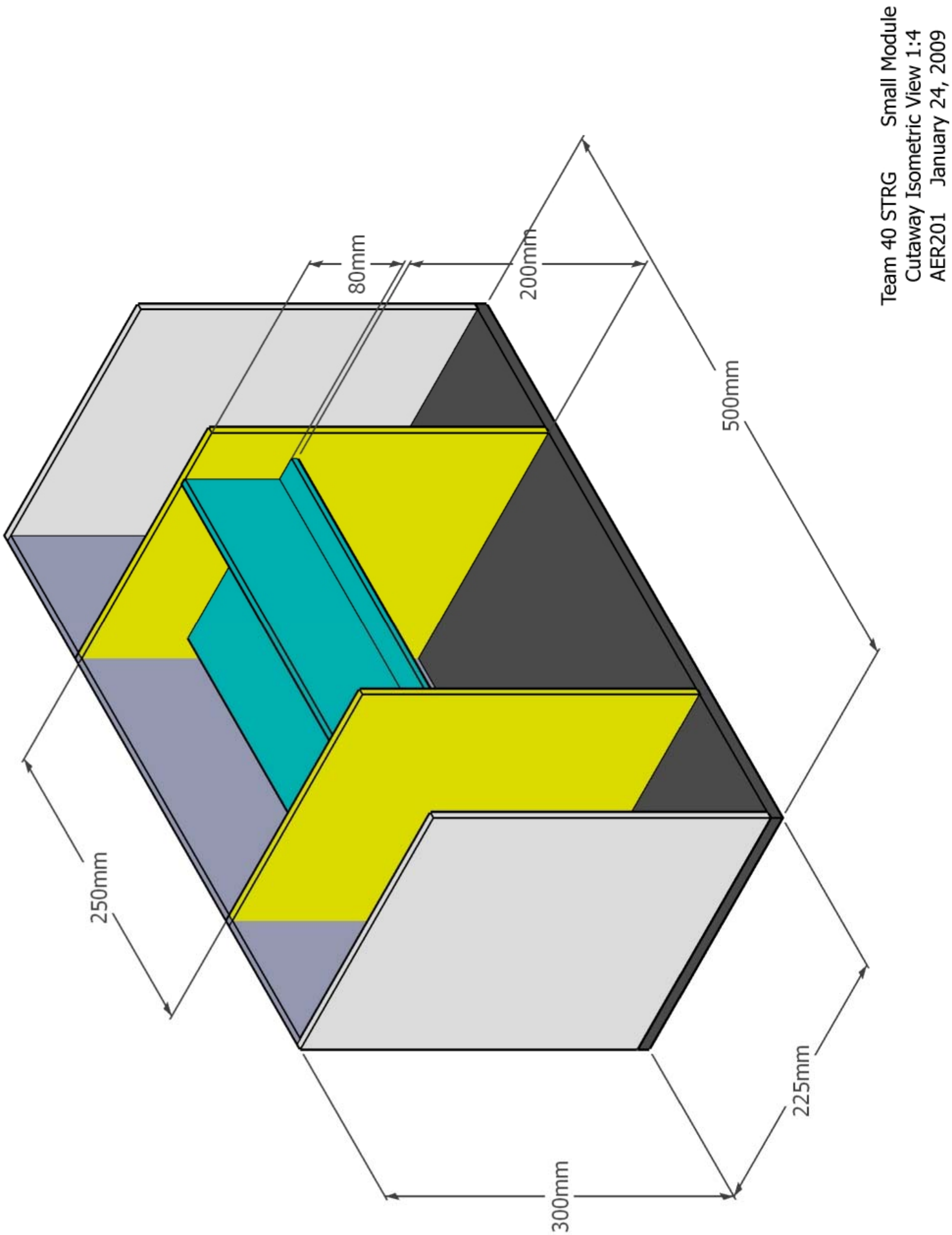
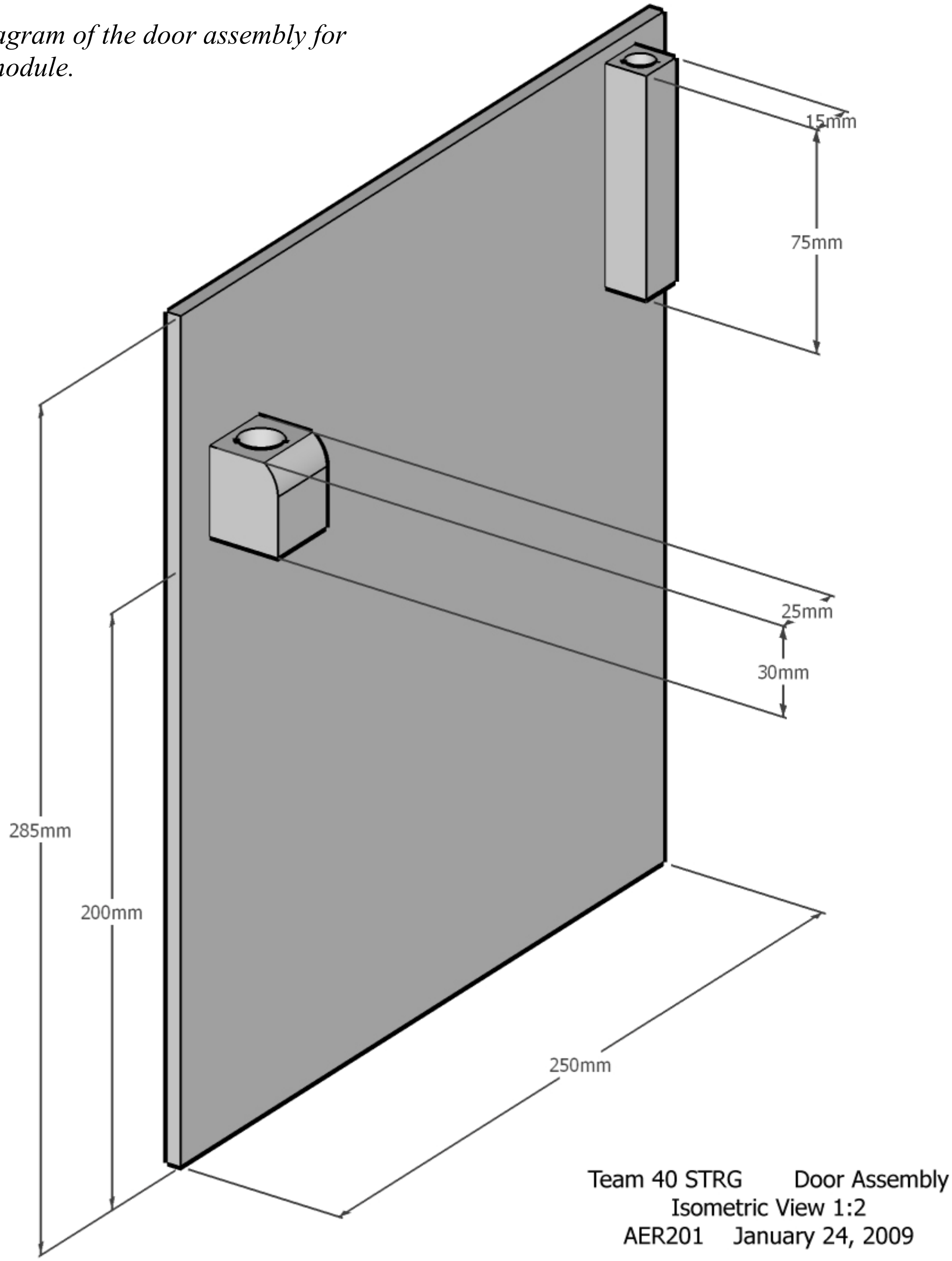


Figure 3: *Detailed cutaway diagram of small module design.*

Figure 4: *Detailed diagram of the door assembly for the small module.*



5.3.2 Locking Mechanism

The locking mechanism will be a simple deadbolt device. A curved protruding block will be attached to the inner face of the door, with a slot for a locking pin (see Figure 4). A solenoid will be mounted vertically on the door frame such that when the system is inactive, the pin will rest in the slot, and prevent the door from opening.

When the operator unlocks the door from the interface, power will be supplied to the solenoid, raising the head, and allowing the door to be opened. After 3 seconds, power will be cut to the solenoid causing the pin to extend. If the door is not opened during this time, the pin will fall back into the hole, and the door will effectively be locked again. If the door is opened, the pin will drop and protrude from the frame. When the door eventually closes, the pin will ride up on the rounded edge of the protruding block, fall into the pin slot and thereby lock the door.

5.3.3 Door Mechanisms

The device for moving the door will consist of two mechanisms: an active device which prevents the door from closing for the desired amount of time, and a passive tension device, which restores the door to its closed state.

The active device is essentially a two-state solenoid with extended and depressed modes, which will jam the door open for the required amount of time if the user opens the door. This will be implemented using the same device used in pens to extend or retract the tip based on pressure application on the back button. Essentially, this device will be mounted vertically on the inside of the door such that in the depressed state, it will be flush with the top of the door. A solenoid will be attached underneath such that it can push the button of the device each time an impulse current is applied. Once the button is pushed, the pen mechanism ensures that the tip will stay in its intended position. This design has a major advantage over other solutions in that the state of the door (jammed open or closed) can be maintained without a continuous application of current, which has residual benefits such as long component lifetime, reliability and low power consumption. When the user unlocks the module, power will be applied for 3 seconds to the jamming solenoid. If the door is not opened during this time, the frame will prevent the tip from extending, and door will have locked. If the door is opened, the tip will extend, and prevent the door from closing again for 15 seconds by jamming between the door and frame. After 15 seconds, power will be applied to the solenoid again, causing the tip to retract and allowing the door to close.

The passive device simply consists of a pair of rubber bands hooked between the back of the module and the door, which constantly acts in tension to close the door. Within 15 seconds of opening, the jams prevent the door from closing, but if the operator wishes to hold the door open beyond this interval, he/she user must apply enough force to open the door against the tension of rubber ties. The calculation for the maximum allowable tension in the rubber ties is based on the moment of inertia of the doors about their hinge. This is calculated as follows:

(1) $$I = \int r^2 \, dm$$

(2) $$I = \int \rho t h x^2 dx$$ (evaluated between x = 0 and x = w)

where ρ is the density of the door, t is the thickness, w is the width, h is the height and x is the distance from the hinge.. With these values, we are then able to find the torque required from the rubber ties to close the door within three seconds (at least $\pi/6$ radians per second in three seconds, or $\pi/12$ rad/s^2). Hence, we can find the force required from the rubber ties (and the force required by the user to keep the door open) by:

(3) $\tau = I\alpha = Fr$

Given that the density of fibreboard is approximately 0.5g/cm^3 [5], the thickness is 2 mm, the dimensions of the biggest door are 60cm (H) x 40cm (W) x 30 cm (D), and the distance of elastic attachment is approximately 5 cm from the hinge, we can estimate the force required to be the following:

$$
\begin{aligned}
I &= \tfrac{1}{3}(\rho t) * hw^3 \\
&= \tfrac{1}{3}(0.5*0.2)*60*40^3 \\
&= 128000 \text{ g*cm}^2 \\
F &= I\alpha/r = 128000*(\pi/12)/5 \\
&= 6702 \text{ g*cm/s}^2 \\
&= 0.07 \text{ N}
\end{aligned}
$$

Therefore, the force required is 0.07 N, which can be handled by a rubber band.

5.4 CIRCUIT SUBSYSTEM

5.4.1 Powering the System

The system will be powered by 110V AC current. A power adapter will convert the AC power to 12V DC and 5V DC for the circuit and microcontroller. A backup battery system will be used when DC power is disconnected. Schottky diodes will be used to prevent drainage of the batteries into the power source and to prevent damage to the board. The 12V source will drive the PIC board and the solenoids, and the 5V source will drive the logic gates and the relays. See Figure 8 in Appendix C for a schematic overview of circuits.

5.4.2 Driving the Solenoids

The solenoid will be driven by 7 output pins from the PIC board. 5 of the 7 signals will designate the box number, while the other 2 signals will denote whether to unlock the doors or to close the doors. The signals will go through a 7-to-10 decoder circuit (see Figure 10 in Appendix C), whose 10 outputs will activate the 10 solenoids (2 in each box).

Each solenoid will be driven by a transistor and a relay. The transistor will drive the relay, which will in turn drive the solenoid. By using a relay as an intermediary in driving the solenoids, the circuitry is protected from interference from the solenoids. For all the door jamming solenoids, a normally-closed manual switch is connected in series with the solenoid. Pressing the switch will activate the solenoid to retract the jam, and allow the doors to be closed manually. See Figure 9 in Appendix C for the schematic of the solenoid driver/control circuit along with calculations for the required resistance between the PIC and transistor.

5.5 MICROCONTROLLER SUBSYSTEM

5.5.1 Program Overview

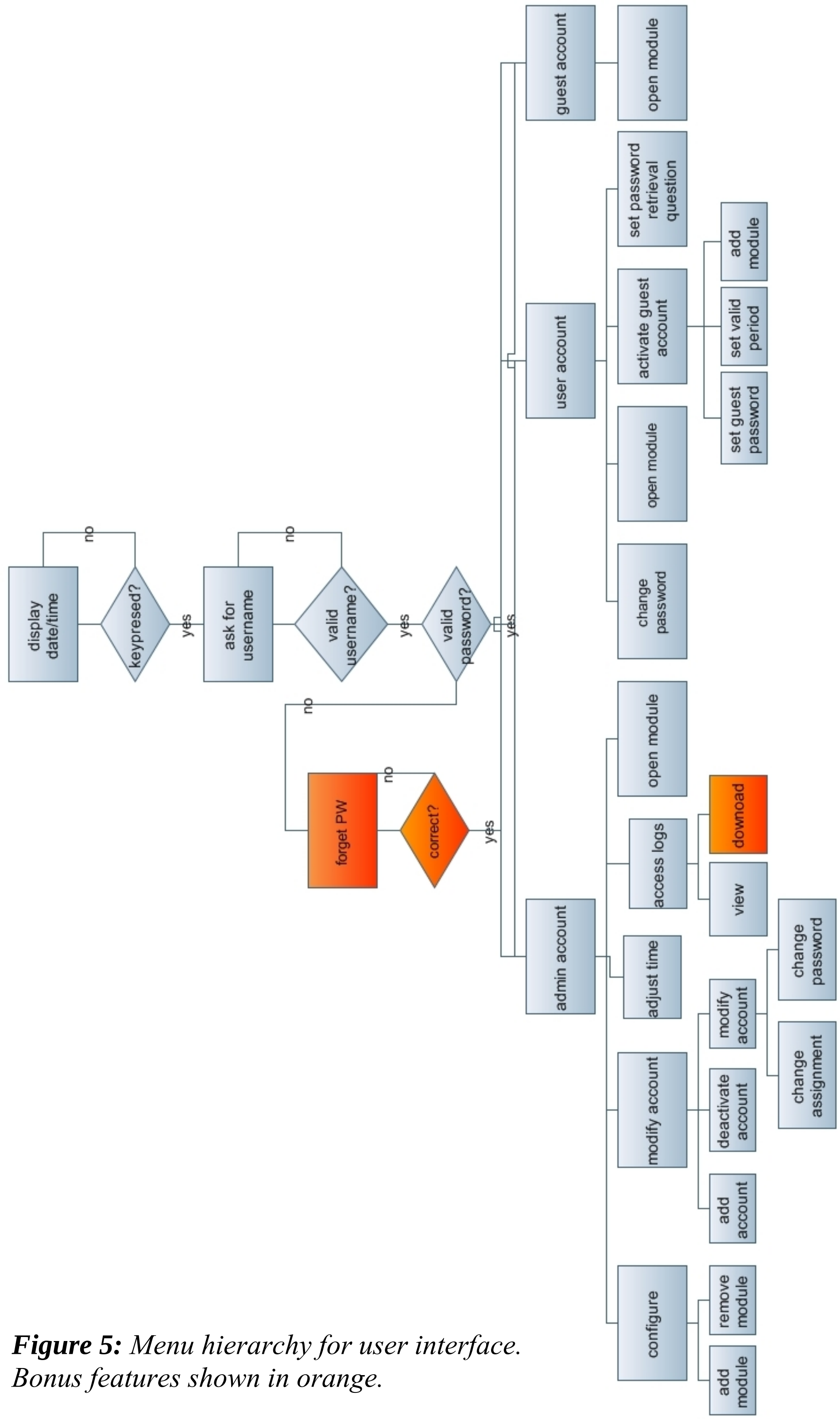


Figure 5: *Menu hierarchy for user interface. Bonus features shown in orange.*

5.5.2 Hardware and Interface

The microcontroller that will be used is the PIC16F877 from MicroChip. The PIC DevBugger board will be used so the PIC's connection to ground, power and the oscillator will already be made. The PIC has five ports which can be used to interface with peripherals, which will be used in the following manner.

Port	Application
A	Pins RA1 to RA5 will be used as input pins for the pushbuttons
B	Used to connect to keypad – pre-connected in DevBugger Board
C	Pins RC1 to RC5 will be used as output pins to identify each module Pin RC6 will be used to signal the lock solenoid. Pin RC7 will be used to signal the door solenoid.
D	Used to connect to LCD – pre-connected in DevBugger Board
E	Port E will not be used

The hardware required for the user interface is a 16 character, 2 line 5x8 pixel LCD display controlled by Hitachi's HD44780 Driver IC and a 4x4 matrix keypad. Data Memory RAM will be used to store variables during runtime, the code itself will be downloaded on to Flash ROM while the activity logs will be stored in EEPROM.

5.5.3 Overview of Actuator Control Program

The flowchart outlining the algorithm for operating the actuators is shown below. This algorithm takes effect whenever the open module command is entered by the operator (see Figure 5).

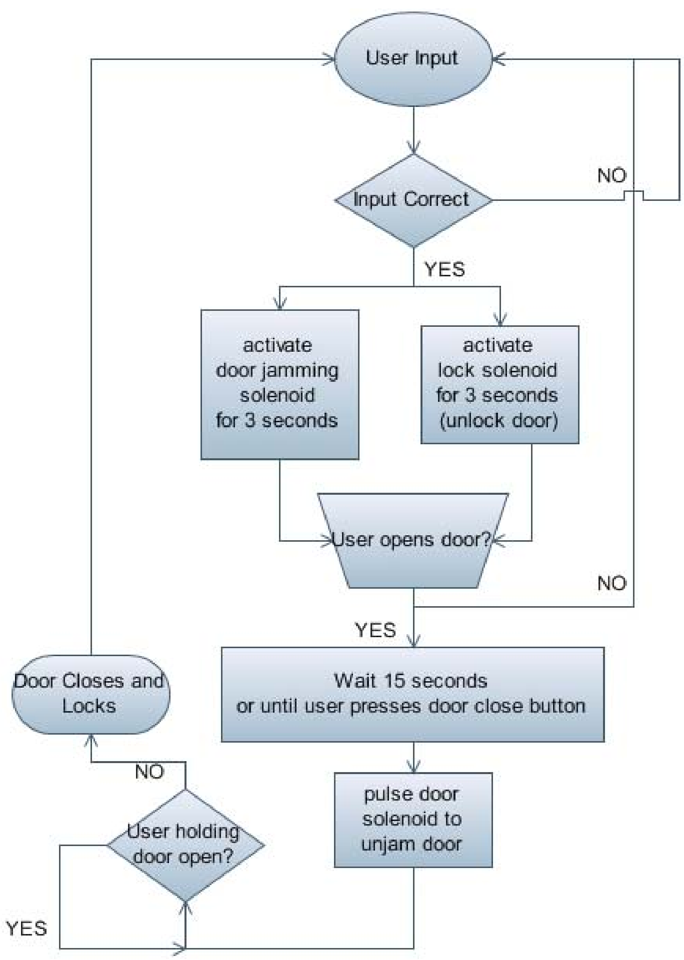


Figure 6: *Algorithm for controlling actuators.*

5.5.3 Pseudocode for Actuators

The following pseudocode illustrates the basic principle used to implement the actuator control algorithm shown in Figure 6. This set-up allows us to implement our design without the use of sensors, while ensuring uninterrupted program flow, thereby reducing complexity.

```
if (open module X command) {           // Operator wants module X opened

        set pin for lock solenoid X high   // Power solenoid to pull rod out of slot - unlocked
        set pin for door solenoid X high   // Power solenoid to push jam upward

        for (3 seconds)     {              // Allow user to open door within 3 seconds
                wait
        }

        set pin for lock solenoid low      // Rod falls down - if door is still closed, it will be
                                           // locked,  else it will slightly protrude below frame
        set pin for door solenoid low      // If the user doesn't open the door, the jam will
                                           // push against the door frame to no effect so jam
                                           // will still be retracted. If the user opens the door,
                                           // solenoid will have pushed jam up already and
                                           // power no longer needed to keep it in place

        activate pushbutton interrupt      // Turn on pushbutton interrupt
                                           // If door was never opened, no way to access
                                           //  pushbutton so no interrupt will occur in the next
                                           // 15 seconds and program will proceed smoothly.

        for (15 seconds){
                process other requests
                if (push button activated){
                        break from loop
                }
        }
        deactivate pushbutton interrupt    // Disable interrupts after 15 seconds elapse or if
                                           // user pushes button

        set pin for door solenoid high     // Power solenoid again, if door was never opened,
                                           // it will jam against frame with no effect. If door
        for (1 second){                    // was opened, the jam is extended and powering the
                wait                       // solenoid again will cause the tip to retract.
        }

        set pin for door solenoid low      // Unpower the door solenoid. If the door is still
}                                          // open it is up to the operator to keep it open.
                                           // Elastic bands will close and lock the door when
                                           // operator is done.

goto main_menu                             // Return to main menu
```

Figure 7: *Pseudocode for controlling actuators.*

6. Project Management

6.1 Division of Labor

The team consists of three members who are responsible for both administrative, conceptual and implementation tasks. Conceptual and administrative tasks must be performed as a group because they require a united vision of all members to ensure success. Implementation tasks will be subdivided into three components, each spearheaded by a team member. For these subsystems, members are still expected to act as the resource person in their field of expertise after the timeline expires, but should be focused more on integration.

Task Category	Members	General Description	Timeline
Administrative	All	All members will attend meetings, plan schedules, engage in correspondence with the customer, help in the preparation of deliverables and procure supplies	Jan. 7 – Apr. 14
Conceptual	All	All members will contribute ideas and feedback regarding both the prototype and the implementation plan.	Jan. 7 – Jan. 25
Electromechanical (EM)	David Wang	Design, analysis, fabrication, assembly and integration of storage modules, and actuation mechanisms	Jan. 9 – Mar. 11
Circuits (CCT)	Fangzhou Su	Acquisition of power supplies and construction of solenoid driver circuits and power circuits. At the end of this subset timeline, circuit member will assist the Microcontroller member in completing and testing code.	Jan. 22 – Mar 2
Microcontroller (MC)	Duluxan Sritharan	Design of program algorithm and development of all software for user interface, equipment interface, and data storage and retrieval	Jan 7 – Mar 3
Integration	All	Integrating all subsystems into a single unit, testing for functionality and debugging any issues that may arise.	Mar 4 – Apr 8

In the following pages, a more detailed list of tasks is given below for each subsystem along with project milestones and their significance. GANTT charts are also included in Appendix E, outlining projected durations and costs involved in performing these tasks. The milestones and tasks mentioned in the following sections are cross-referenced with the GANTT charts.

6.2 TASKS FOR ELECTROMECHANICAL MEMBER

6.2.1 Pre-production

- Outline functionality of each moving component
- Characterize the performance of various actuators
  - Force
  - Power requirement
  - Size
  - Price
- Revise technical drawings based on dimensions of selected motors/solenoids
- Test the pushing/pulling power of solenoids without attachment to circuitry
- Complete "mule" prototype
  - Attach solenoids and springs to module
  - Power with batteries
  - Finalize fabrication techniques
  - Solve geometric constraint issues

6.2.2 Production

- Obtain moving parts and structural components
- Fabricate module one at a time
  - Frame construction
  - Hinge and spring attachment
  - Solenoid attachment
  - Wiring
- Test functionality of each without attaching to circuitry

6.2.3 Post-production

- Module integration and testing
  - Connect to circuit board and microcontroller
- Final troubleshooting

6.3 TASKS FOR CIRCUIT MEMBER

6.3.1 Prototyping

- Obtain required voltage from electromechanical member
- Design overall circuitry
- Explore possibilities of interference
- Design specific circuit diagrams
  - Driver circuit
  - Solenoid circuit
  - Power-battery circuit
  - Manual switch circuit

- Obtain data on voltage, current, power rating for components
- Create circuit on protoboard for testing
    - Testing with MC output signals for driver circuit
    - Testing power supply with multimeter
- Finalize overall voltage, current, power requirement
- Obtain components and parts for soldering

6.3.2 Soldering

- Driver circuit
    - Logical gates
    - connections
- Solenoid circuit
    - Transistors
    - Relays
    - Manual switches
- Testing with MC output signals
- Power-battery circuit
    - Testing power supply with PIC board
- Overall connections

6.3.3 Subsystem Integration and debugging

- Connecting circuits
- Convergence with microcontroller
    - Set up functions to debug and test circuits
    - Assist in creating timing functions to ensure constraints are met
    - Test to see if all signals are amplified correctly
    - Test to see if pushbuttons are functioning correctly
    - Testing power supply
- Interfacing with actuators
    - Test to see if all actuators are driven properly
- Final troubleshooting

6.4 TASKS FOR MICROCONTROLLER MEMBER

6.4.1 Preparation

- Familiarization with PIC and peripheral interfacing
- Problem definition
- Flowchart creation
- Familiarization with MPLAB IDE
- Creation of pseudo-code

6.4.2 User Interface

- Coding main template with basic definitions
- Coding functions for LCD interface
    - Code function to display arbitrary strings
    - Code function to move cursor
- Debugging and integrating LCD interface
- Coding functions for keypad interface
    - Code function to read string
    - Implement process for entering all alphanumeric characters on 4x4 keypad
- Debugging and integrating keypad interface
- Coding functions for menu traversal
    - Code functions to travel up and down menu hierarchy
    - Code functions to scroll up and down on the screen
- Debugging and integrating menu traversal
- Integrating all user interface functions
    - Ensure that what the user types appears appropriately on the LCD
    - Ensure that scrolling and menu traversal works appropriately

6.4.3 Mechanism Interface

- Code for Solenoids
    - Write function to set appropriate pins for solenoids high and low
- Code for Pushbuttons
    - Write function that detect which pushbutton was detected
- Debugging and integrating mechanical interface

6.4.4 Data Structures and Storage

- Coding functions for EEPROM storage
    - Devise hash algorithm for storing account data
    - Write function to traverse and retrieve data from EEPROM
- Coding data structures for account information
    - Devise data structures to store account IDs, passwords and module assignment
    - Write functions to store this data efficiently
- Integrating data structures and data storage
    - Write functions to ensure data structures are stored in RAM properly

6.4.4 Subsystem Integration and Testing

- Combine user and actuator interface (with Circuit member – MC specific roles listed)
    - Set up functions to convey user input to actuator code
    - Implement procedural logic shown in pseudocode
- Subsystem integration and debugging
    - Test to see if commands on keypad correspond to what is displayed on LCD
    - Test if open module command produces high voltage on correct pins

6.5 MILESTONES

A chronological list of milestones, along with the nature of each milestone is listed in the following table. The milestones marked in the GANTT Chart correspond to those outlined below.

No.	Date	Members	Milestone Description
1	Jan 9	All	*Deliverable:* Team finalized and subsystem responsibilities assigned.
2	Jan 15	EM	All drawings should be completed and overall concept of actuator system to be used should be decided.
3	Jan 15	MC	The microcontroller should have a solid idea of the program structure, and a general understanding of how to interface with the user and the system. The team will be informed of progress to date to garner any feedback.
4	Jan 26	All	*Deliverable:* Design proposal outlining conceptual design phase and selected solution should be complete and submitted.
5	Jan 26	CCT	Overall circuit design complete.
6	Jan 29	EM	Material selection finalized and solenoids purchased and installed in mule prototype.
7	Jan 29	MC	The user interface will be complete allowing for complete menu traversal and interaction. However, user prompts are not expected to produce any mechanical response and are symbolic only.
8	Jan 29	CCT	Specific circuit designs and component calculations complete
9	Feb 4	EM	*Individual Evaluation 1:* Completion of small modules including fabrication, installation of solenoids, and testing
10	Feb 4	MC	*Individual Evaluation 1:* The code for running the keypad and LCD along with the first version of the machine interface will be complete and functional.
11	Feb 4	CCT	*Individual Evaluation 1:* All prototyping done, circuits designs finalized and ready for soldering. Calculations of power complete, all components acquired
12	Feb 11	All	*Deliverable:* Submit notebooks containing all project and design activities.
13	Feb 16	EM	Full completion of medium modules including fabrication, installation of solenoids and testing.
14	Feb 16	MC	All data structures must be implemented and the administrator must be able to access all logs from EEPROM.
15	Feb 25	EM	*Individual Evaluation 2:* Completion of large module including fabrication, installation of solenoids, and testing
16	Feb 25	MC	*Individual Evaluation 2*: The Microcontroller member will have completed the final assembly code and downloaded it onto the PIC to demonstrate its functionality.
17	Feb 25	CCT	*Individual Evaluation 2*: Circuit soldering complete, all sub-circuits functional and debugged.

18	Mar 11	All	*Team Evaluation 1:* The system should be integrated and demonstrate some basic functionalities.
19	Mar 25	All	*Team Evaluation 2:* The system is expected to be completely functional except for very minor bugs.
20	Apr. 8	All	*Public Demonstration:* The prototype will be presented to the public and the team will field any questions.
21	Apr 14	All	*Deliverable:* The final report outlining the team's process and prototype in detail will be completed and submitted.
22	Apr 14	All	*Deliverable:* Each member of the team will submit his design notebook with all design and project activities performed over the semester.

6.6 PROCESS EVALUATION/REVIEW MECHANISMS

The likelihood of the design process in delivering a functional prototype can be gauged on the basis of several review mechanisms. These tools allow project management to alter schedules to meet milestones and review expenditures to meet the budget, as outlined by the customer. The review mechanisms also allow the customer to have a high degree of transparency in evaluating the progress of the team and provide opportunities for feedback and discussion between management and the customer.

Review Mechanism	Description
Team Meetings	Biweekly meetings allow team members to provide feedback, engage in discussion and ensure the project remains on track internally.
Customer Consultations	The team will engage in correspondence with the customer at least once a week either directly in lectures or the lab, or indirectly through e-mail to ask questions and obtain feedback.
TA Consultations	The TA will be informed of all progress on a weekly basis in labs. His expertise in electromechanical and circuit tasks will be actively sought and any feedback will be incorporated.
Adherence to Milestones	All efforts will be made to finish specific tasks within the periods outlined in the GANTT chart. Moreover, it is paramount that all milestones especially are met. This mechanism provides the customer with a basis for evaluating team progress
Adherence to Budget	Efforts will be made to limit development costs to those outlined in the GANTT chart. Failure to do so indicates that an unforeseen problem may have arisen that requires intervention.
Quality of Deliverables	This mechanism allows the user to have detailed documentation of progress to date and evaluate the team's performance based on the quality of deliverables. These evaluations also inform project management of the quality of their design process and product.

6.7 PRODUCT EVALUATION

The final product can be qualified based on whether it satisfies the constraints of the presentation evaluation. This includes:

- Modularity (five modules are configurable/stackable in any combination)
- Structural integrity (able to hold 1 kg weight and the weight of other modules)
- Proper functionality (unlocks, opens, and closes successfully within allotted time)
- Security (is not easy able to be broken into)
-

Upon qualification, the product can be evaluated on a point scale in accordance with the RFP. A score above 2500 is an indication that the prototype is a successful proof of concept.

Category	Evaluation Basis	Points
Functionality	All administrative functions operational	700
	All user functions operational	1000
	All guest functions operational	500
Interface/Data Storage	Account activity logs correctly recorded	700
	User-friendly interface	200
Usability	System robustness, sturdiness and durability	1000
	Ease and security of module attachment	500
	Quick set-up of system	200
Bonus	Displays date and time	200
	Allows activity logs to be downloaded to PC	500
	Password Retrieval	200

7. BUDGET

Item	Quantity	Unit Cost	Total Cost
Electromechanical Components			
Pushing Solenoid (Door Jam)	5	$2.99	$14.95
Pulling Solenoid (Lock)	5	$2.49	$12.45
Two-State Actuator (Pen)	5	$0.20	$1.00
Hardboard	2 – 24” x 48” sheets	$2.48	$4.96
Cardboard	5 – 48” x 96” sheets	$0.58	$2.90
Hinges	5	$0.99	$4.95
Switches	5	$1.49	$9.95
Velcro	Pack of 32 – 7/8” x 7/8” pads	$4.99	$9.98
		Electromechanical Total:	*$61.14*
Circuit Components			
Power Supply	1	$12.00	$12.00
PCB Board	1	$10.00	$10.00
Rechargeable Battery	1	$20.00	$20.00
Signal Transistors	10	$0.50	$5.00
Relays	10	$1.60	$16.00
Logic Gate Chips	-	-	$1.50
Circuit Diodes	25	$0.10	$2.50
Power Supply Diodes	2	$1.00	$2.00
Wires and Cables	-	-	$1.50
		Circuit Total:	*$73.00*
Microcontroller Components			
PIC DevBugger Board	1	$50.00	$50.00
Keypad/LCD	-	-	$6.00
		Microcontroller Total:	*$56.00*
TOTAL			**$192.64**

While the total projected cost of the prototype is very close to the limit of $200, we have every confidence that the prototype will be completed under budget. Some of the project estimations such as the cost of the rechargeable battery are very liberal, in anticipation of a cheaper source. Also some household items such as pens, Velcro and cardboard were assigned more than their face value. Finally, throughout the entire design process, the team has placed on emphasis on simplicity so the risk of unforeseen costs is minimal. As such, management is assured that the prototype can be completed within budget. Projected development costs for the prototype are indicated on a task-by-task basis on the GANTT Charts (Appendix E), and are expected to total $1045. Costs of specialty parts were derived by contacting suppliers (see Appendix B).

8. CONCLUSION

This design will succeed because of its simplicity and its manufacturability. For each module, two solenoid are used – one for the locking mechanism and another to jam the door. The actuators are implemented in a way that maximizes usability and reliability. Extensions to the prototype including constructing the walls of the module out of more robust materials before releasing it to the market, and providing the user with a larger LCD display to increase usability. Another important extension is to add more modules to the prototype to simulate real conditions under which it might be used.

A possible bottleneck may occur in the week of Feb 23, because the Microcontroller needs to ensure that the actuator interface is functional without the guarantee that the Circuits are in place. This bottleneck can be resolved by simulating the code on MPLAB IDE to ensure theoretical functionality, and putting forth a more intensive effort during the system integration phase. The customer should rest assured that Team 40 will do everything in its power to ensure that a fully functional proof-of-concept prototype is delivered on time and on budget.

APPENDIX A: REFERENCES

[1] M. R. Emami. AER201 Engineering Design Course Notes. Toronto: McGraw-Hill Ryerson, 2009.

[2] Self Storage Association. “Self Storage Association Factsheet” Accessed January 20, 2009. Available HTTP: http://www.selfstorage.org/SSA/Home/AM/ContentManagerNet/ContentDisplay.aspx?Section=Home&ContentID=3900

[3] Industore. “Hanel: Multi-Space” Accessed January 14, 2009. Available HTTP: http://www.industore.co.uk/multi-space.php

[4] US Patent Office. “Automated Storage System (US20080208389)”. Accessed January 16, 2009. Available HTTP: http://www.patents.com/AUTOMATED-STORAGE-SYSTEM/US20080208389/en-US/

[5] Akers, L. E. (1966). Particle Board and Hardboard. Oxford: Pergamon Press

[6] M.R. Emami. Lecture: Circuits – Transistors (January 23, 2009 at MB128), AER201.

APPENDIX B: SUPPLIERS

Active Surplus
347 Queen Street West, 2nd Floor
Toronto, ON
M5V 2A4
(416) 593-0909
www.activesurplus.com

AER201 Design Store
Sandford Fleming Building
10 King's College Road, Room 3302
Toronto, ON
M5S 3G4

Creatron
255 College St.
Toronto, ON
http://www.creatroninc.com/contact_us.php

Home Depot
428 Ellesmere Road
Scarborough, ON
M1R 4E6
(416) 609-1800

Home Hardware
306 College St.
St. Toronto, ON, Canada

Office Depot
32 Steeles Avenue West
Thornhill, ON
L4J7Y1

Paper Mart
5361 Alexander St.
Los Angeles, CA
90040

Sayal
3791 Victoria Park Ave.,
Units 1-5
Toronto, Ontario
Canada M1W 3K6
http://www.sayal.com/

APPENDIX C: CIRCUIT SCHEMATICS

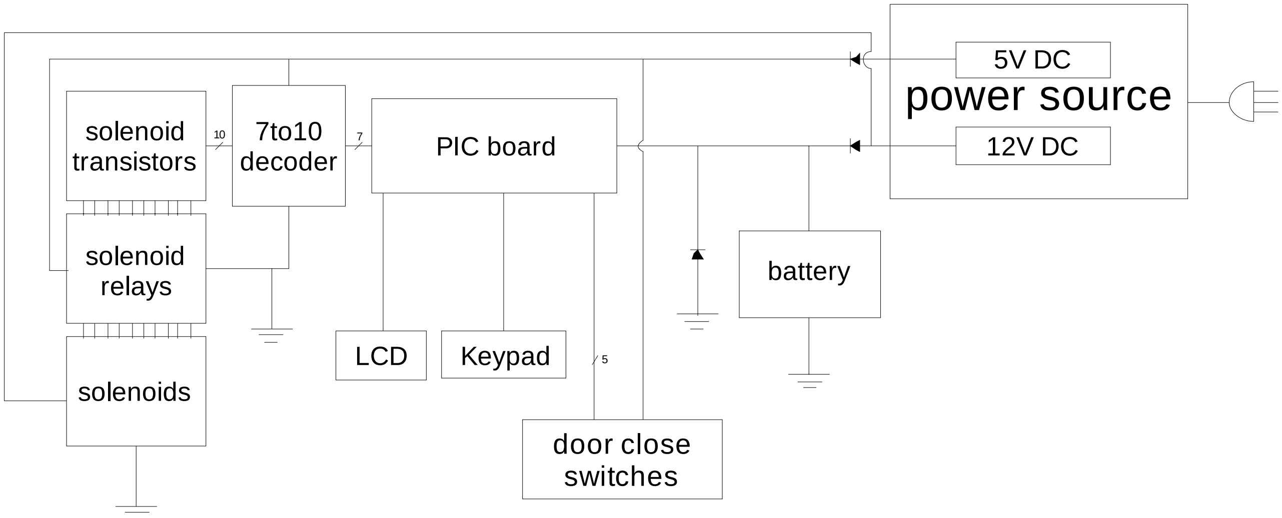


Figure 8: Overall circuit schematic for the system.

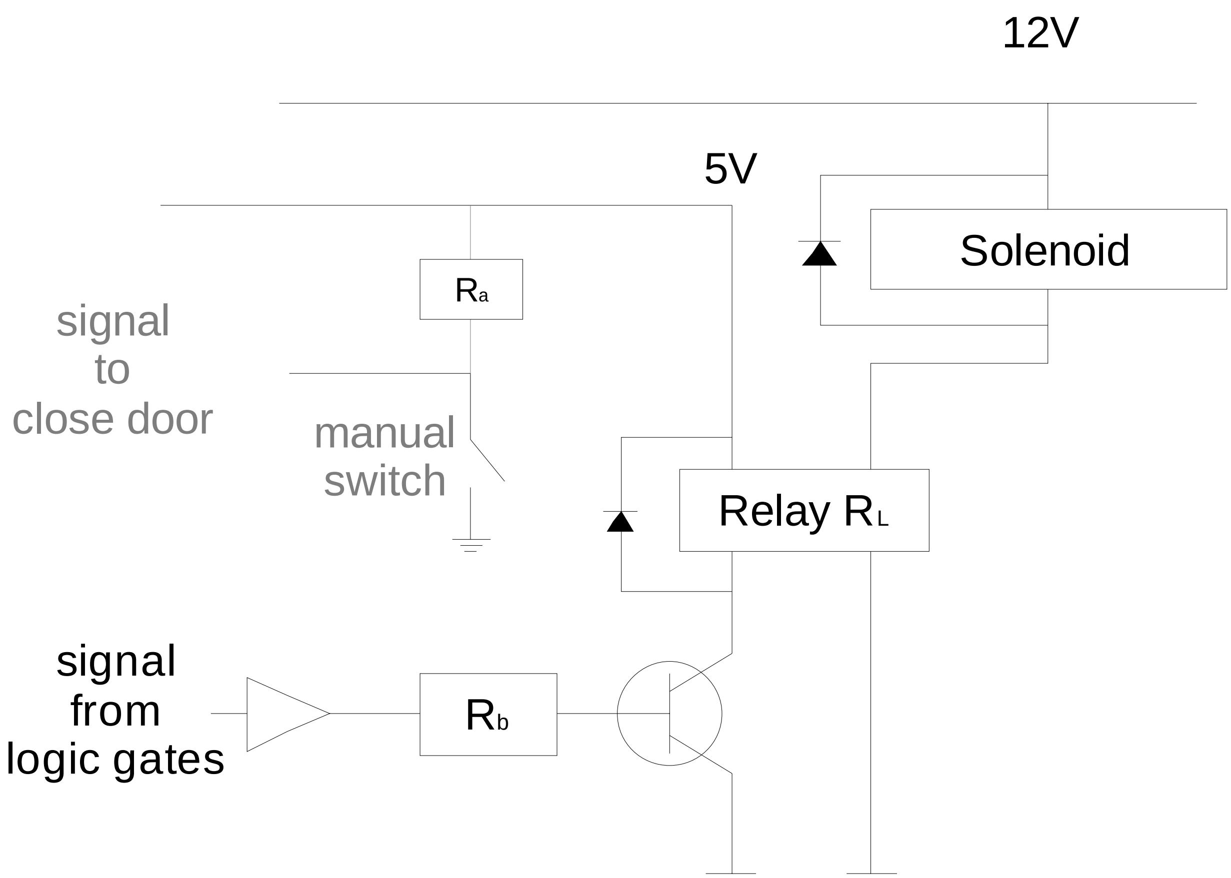


Figure 9: Solenoid Driver and Control Circuit

The resistance required between the PIC and the transistor, R_b, (see Figure 9) can be determined by the following equation [6]:

$$R_b = \frac{R_l \times h_{FE}}{5} \ \ where\ h_{FE} > 5\,\frac{I_l}{\max IC\ current}$$

For the transistor currently chosen (TIP141), $h_{FE} = 1000$ and $R_l = 130\ \Omega$, so $R_b = 26\ \mathrm{k}\ \Omega$

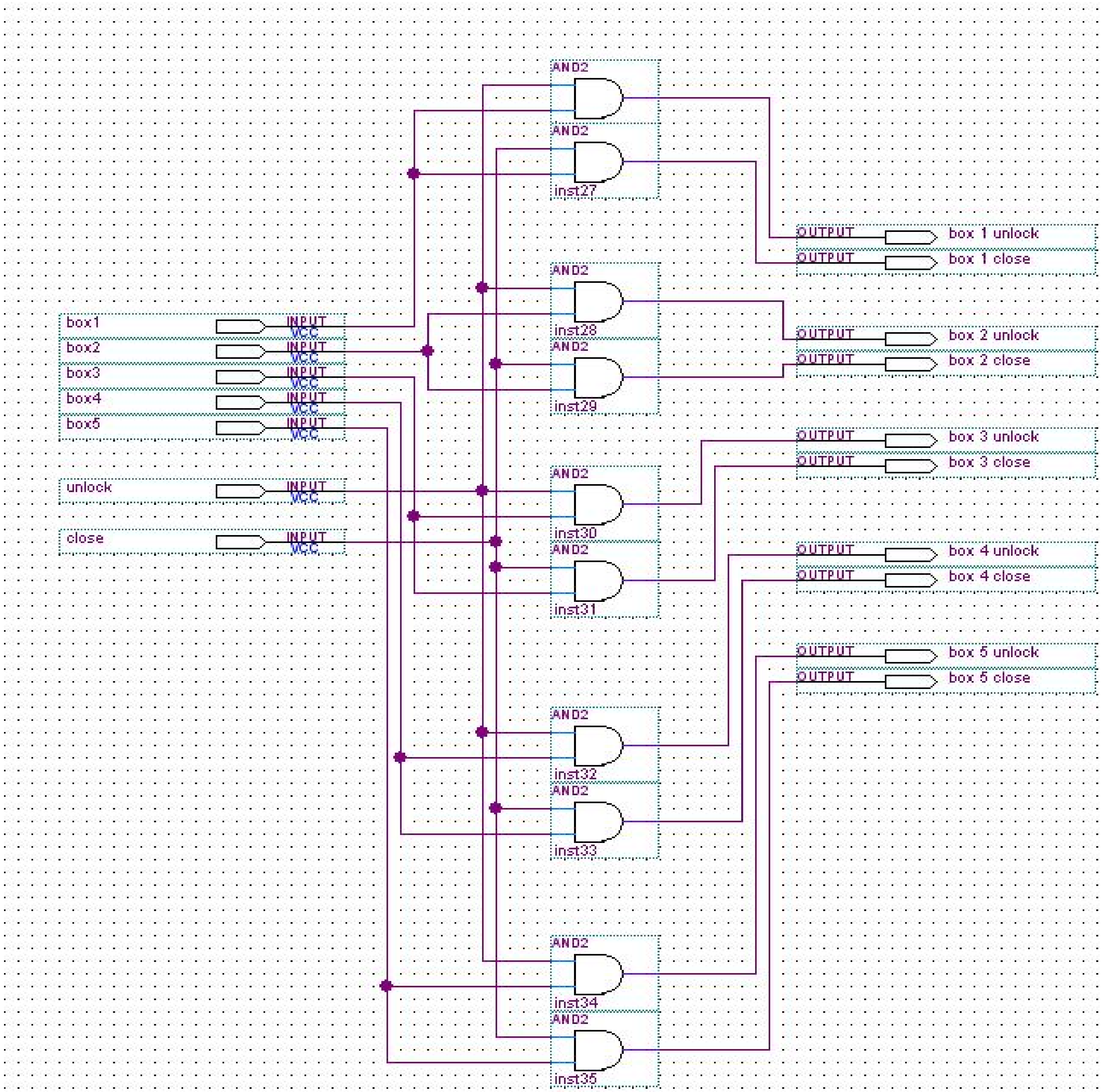
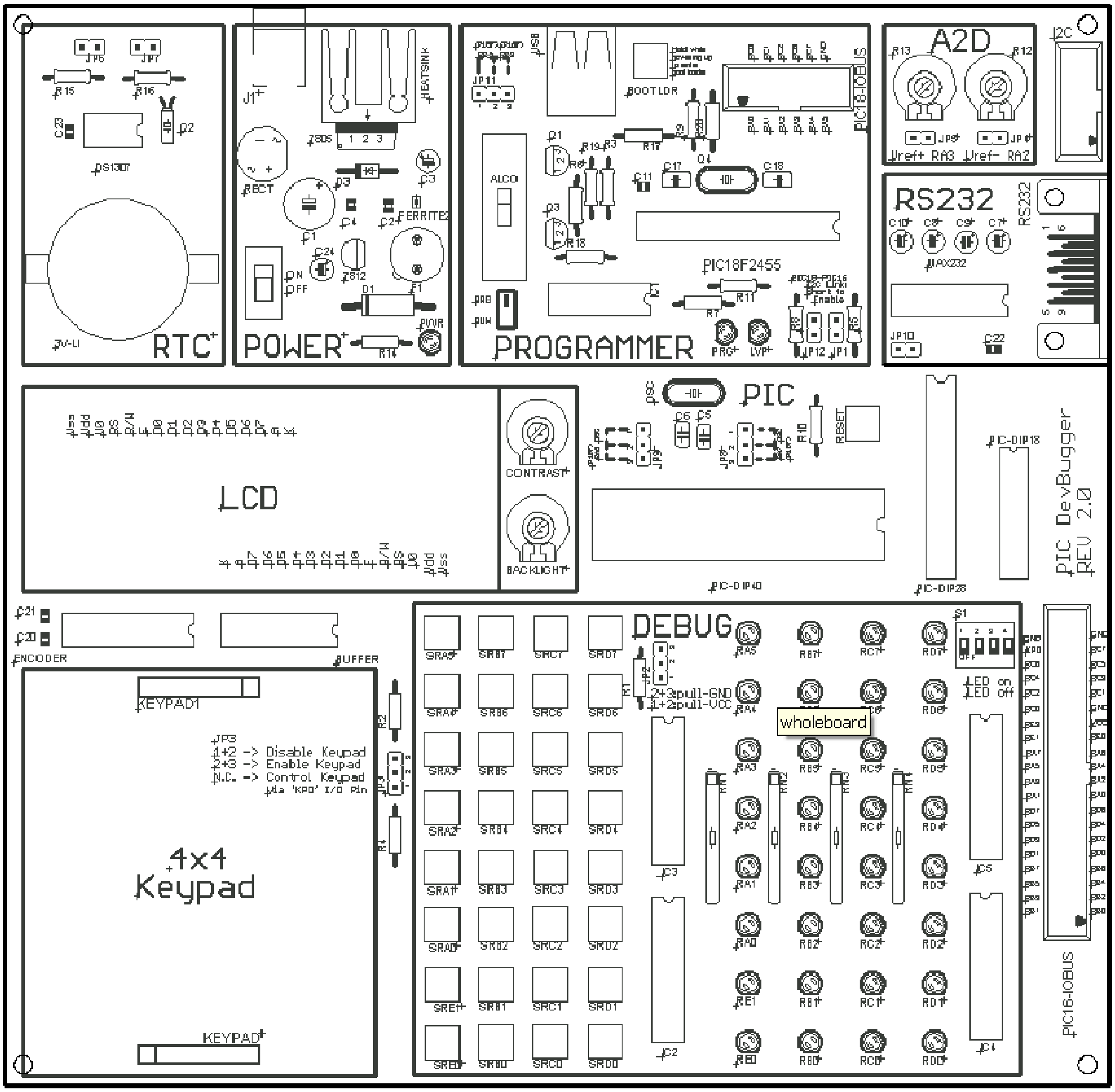


Figure 10: 7 to 10 Decoder Circuit

APPENDIX D: DATASHEETS

PIC DevBugger Manual



MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

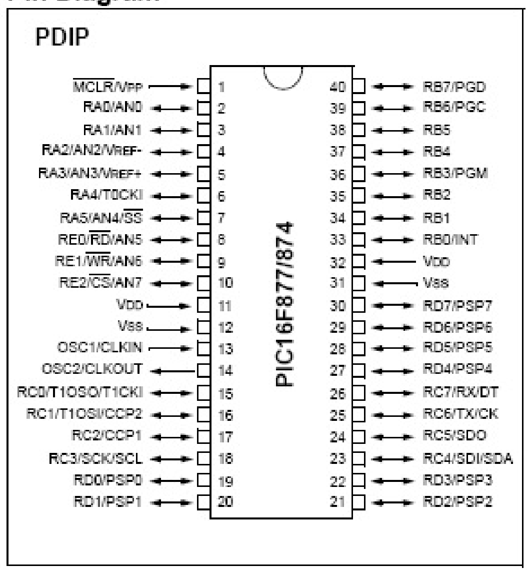
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and
  Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

LM016L·LM016XMBL

- 16 character x 2 lines
- Controller LSI HD44780 is built-in (See page 79).
- +5V single power supply
- Display color: LM016L : Gray
  LM016XMBL : New-gray

MECHANICAL DATA (Nominal dimensions)

Module size .... 84W x 44H x 10.5T (max.) mm
Effective display area .... 61W x 15.8H mm
Character size (5 x 7 dots) .... 2.96W x 4.86H mm
Character pitch .... 3.55 mm
Dot size .... 0.56W x 0.66H mm
Weight .... about 35 g

ABSOLUTE MAXIMUM RATINGS

	min.	max.
Power supply for logic ($V_{DD}-V_{SS}$)	0	6.5 V
Power supply for LCD drive ($V_{DD}-V_O$)	0	6.5 V
Input voltage (Vi)	V_{SS}	V_{DD} V
Operating temeprature (Ta)	0	50 40* °C
Storage temperature (Tstg)	−20	70 60* °C

* Shows the value of type LM016XMBL.

ELECTRICAL CHARACTERISTICS

Ta = 25°C, V_{DD} = 5.0 V ± 0.25 V

Input "high" voltage (V_{IH}) .... 2.2 V min.
Input "low" voltage (V_{IL}) .... 0.6 V max.
Output "high" voltage (V_{OH}) ($-I_{OH}$ = 0.2 mA) .. 2.4 V min.
Output "low" voltage (V_{OL}) (I_{OL} = 1.2 mA) .... 0.4 V max.
Power supply current (I_{DD}) (V_{DD} = 5.0 V) .. 1.0 mA typ.
3.0 mA max.

POWER SUPPLY FOR LCD DRIVE (Recommended) (V_{DD}-V_O)

Duty = 1/16
Range of $V_{DD}-V_O$ .... 1.5~5.25 V
Ta = 0°C .... 4.6 V typ.
Ta = 25°C .... 4.4 V typ.
Ta = 50°C .... 4.2 V typ.

OPTICAL DATA .... See page 7

INTERNAL PIN CONNECTION

Pin No.	Symbol	Level	Function	
1	V_{SS}	–	0V	Power supply
2	V_{DD}	–	+5V	
3	V_O	–	–	
4	RS	H/L	L: Instruction code input H: Data input	
5	R/W	H/L	H: Data read (LCD module→MPU) L: Data write (LCD module←MPU)	
6	E	H, H→L	Enable signal	
7	DB0	H/L	Data bus line Note (1), (2)	
8	DB1	H/L		
9	DB2	H/L		
10	DB3	H/L		
11	DB4	H/L		
12	DB5	H/L		
13	DB6	H/L		
14	DB7	H/L		

Notes:

In the HD44780, the data can be sent in either 4-bit 2-operation or 8-bit 1-operation so that it can interface to both 4 and 8 bit MPU's.

(1) When interface data is 4 bits long, data is transferred using only 4 buses of DB_4~DB_7 and DB_0~DB_3 are not used. Data transfer between the HD44780 and the MPU completes when 4-bit data is transferred twice. Data of the higher order 4 bits (contents of DB_4~DB_7 when interface data is 8 bits long) is transferred first and then lower order 4 bits (contents of DB_0~DB_3 when interface data is 8 bits long).

(2) When interface data is 8 bits long, data is transferred using 8 data buses of DB_0~DB_7.

Unit: mm

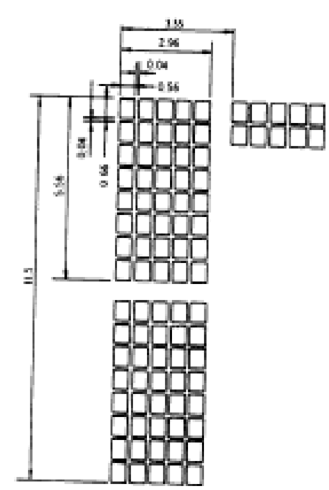


Fig. 1 Display pattern

NTE ELECTRONICS, INC.
44 FARRAND STREET
BLOOMFIELD, NJ 07003
(973) 748–5089

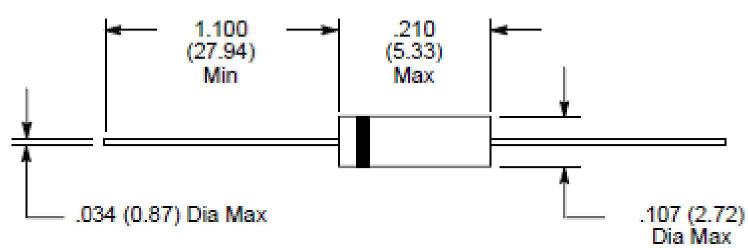
NTE586
Silicon Rectifier Diode
Schottky Barrier, Fast Switching

Features:
- Low Switching Noise
- Low Forward Voltage Drop
- High Current Capability
- High Reliability
- High Surge Capability

Maximum Ratings and Electrical Characteristics: (T_A = +25°C unless otherwise specified. Single phase, half wave, 60Hz, resistive or inductive load. For capacitive load, derate current by 20%.

Maximum Recurrent Peak Reverse Current 40V
Maximum RMS Voltage 28V
Maximum DC Blocking Voltage 40V
Maximum Average Forward Rectified Current (375" . (9.5mm) lead length at T_L = +95°C) . . . 3.0A
Peak Forward Surge Current
(8.3ms single half sine–wave superimposed on rated load T_L = +75°C) 80A
Maximum Instantaneous Forward Voltage at 3A DC (Note 1) 525V
Maximum Average Reverse Current at Rated DC Blocking Voltage
T_A = +25°C 1.0mA
T_A = +100°C 10mA
Typical Thermal Resistance, Junction–to–Ambient (Note 2), R_{thJA} . . . . 80°C/W
Typical Junction Capacitance (Note 3) 110pF
Operating Junction Temperature Range T_J . . . . –65° to +125°C
Storage Temperature Range T_{STG} . . . . –65° to +125°C

Note 1. measured at Pulse Width 300µs, Duty Cycle 2%.
Note 2. Thermal Resistance Junction to Ambient Vertical PC Board Mounting, 0.5" (12.7mm) Lead Length.
Note 3. Measured at 1MHz and applied reverse voltage of 4.0 Volts.



Color Band Denotes Cathode

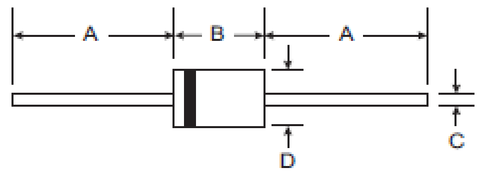
DIODES INCORPORATED

1N4001/L - 1N4007/L

1.0A RECTIFIER

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- **Lead Free Finish, RoHS Compliant (Note 4)**



Dim	DO-41 Plastic		A-405	
	Min	Max	Min	Max
A	25.40	—	25.40	—
B	4.06	5.21	4.10	5.20
C	0.71	0.864	0.53	0.64
D	2.00	2.72	2.00	2.70
All Dimensions in mm				

"L" Suffix Designates A-405 Package
No Suffix Designates DO-41 Package

Mechanical Data

- Case: DO-41, A-405
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020C
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Last Page
- Marking: Type Number
- Weight: DO-41 0.30 grams (approximate)
  A-405 0.20 grams (approximate)

Maximum Ratings and Electrical Characteristics

@ $T_A = 25°C$ unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N 4001/L	1N 4002/L	1N 4003/L	1N 4004/L	1N 4005/L	1N 4006/L	1N 4007/L	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ $T_A = 75°C$	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load (JEDEC Method)	I_{FSM}	30							A
Forward Voltage @ $I_F = 1.0A$	V_{FM}	1.0							V
Peak Reverse Current @ $T_A = 25°C$ at Rated DC Blocking Voltage @ $T_A = 100°C$	I_{RM}	5.0 50							µA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							°C
Operating and Storage Temperature Range (Note 3)	T_j, T_{STG}	-65 to +150							°C

Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
2. Measured at 1. MHz and applied reverse voltage of 4.0V DC.
3. JEDEC Value.
4. RoHS revision 13.2.2003. Glass and High Temperature Solder Exemptions Applied, see *EU Directive Annex Notes 5 and 7*.

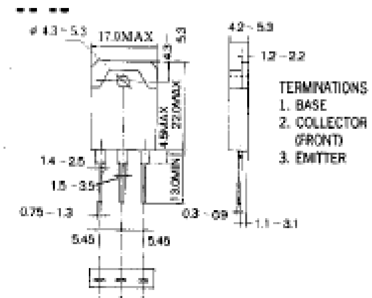
TIP140/141/142

NPN EPITAXIAL
SILICON DARLINGTON TRANSISTOR

HIGH DC CURRENT GAIN

- Complementary to TIP145/146/147

SC-65



ABSOLUTE MAXIMUM RATINGS (T_a=25℃)

Characteristic	Symbol	Rating	Unit
Collector-Base Voltage :TIP140	VCBO	60	V
TIP141		80	V
TIP142		100	V
Collector-EmitterVoltage :TIP140	VCEO	60	V
TIP141		80	V
TIP142		100	V
Emitter-Base voltage	VEBO	5	V
Collector Current (DC)	IC	10	A
Collector Current (Pulse)		15	A
Base Current (DC)	IB	0.5	A
Collector Dissipation (Tc=25℃)	PC	125	W
Junction Temperature	Tj	150	℃
Storage Temperature	Tstg	-50~150	℃

Quad 2-input AND gate 74HC08; 74HCT08

FEATURES

- Complies with JEDEC standard no. 8-1A
- ESD protection:
  HBM EIA/JESD22-A114-A exceeds 2000 V
  MM EIA/JESD22-A115-A exceeds 200 V.
- Specified from −40 to +85 °C and −40 to +125 °C.

DESCRIPTION

The 74HC/HCT08 are high-speed Si-gate CMOS devices and are pin compatible with low power Schottky TTL (LSTTL). They are specified in compliance with JEDEC standard no. 7A. The 74HC/HCT08 provide the 2-input AND function.

QUICK REFERENCE DATA

GND = 0 V; T_{amb} = 25 °C; $t_r = t_f$ = 6 ns.

SYMBOL	PARAMETER	CONDITIONS	TYPICAL		UNIT
			74HC08	74HCT08	
t_{PHL}/t_{PLH}	propagation delay nA, nB to nY	C_L = 15 pF; V_{CC} = 5 V	7	11	ns
C_I	input capacitance		3.5	3.5	pF
C_{PD}	power dissipation capacitance per gate	notes 1 and 2	10	20	pF

Notes

1. C_{PD} is used to determine the dynamic power dissipation (P_D in μW).
   $P_D = C_{PD} \times V_{CC}^2 \times f_i \times N + \Sigma(C_L \times V_{CC}^2 \times f_o)$ where:
   f_i = input frequency in MHz;
   f_o = output frequency in MHz;
   C_L = output load capacitance in pF;
   V_{CC} = supply voltage in Volts;
   N = total load switching outputs;
   $\Sigma(C_L \times V_{CC}^2 \times f_o)$ = sum of the outputs.
2. For 74HC08: the condition is V_I = GND to V_{CC}.
   For 74HCT08: the condition is V_I = GND to V_{CC} − 1.5 V.

FUNCTION TABLE

INPUT		OUTPUT
nA	nB	nY
L	L	L
L	H	L
H	L	L
H	H	H

Note

1. H = HIGH voltage level;
   L = LOW voltage level.

STA® Pull Tubular Solenoids — 3/4" Dia. x 1-1/2"

Part Number: 195204 - X XX

All catalog products manufactured after April 1, 2006 are RoHS Compliant

Coil AWG Number (from performance chart below)

Plunger Configurations and anti-rotation flat on mounting
1 Flat face plunger without anti-rotation flat
2 60° plunger without anti-rotation flat
5 Flat face plunger with anti-rotation flat
6 60° plunger with anti-rotation flat

- Well-suited for battery operation.

See the "Battery Operated Solenoids" section for complete information.

LINEAR Tubular

Performance

Maximum Duty Cycle			100%	50%	25%	10%
Maximum ON Time (sec) when pulsed continuously[1]			∞	230	25	6
Maximum ON Time (sec) for single pulse[2]			∞	265	63	15
Watts (@ 20°C)			7	14	28	70
Ampere Turns (@ 20°C)			855	1200	1700	2700
Coil Data						
awg (0XX)[3]	Resistance (@20°C)	# Turns[4]	VDC (Nom)	VDC (Nom)	VDC (Nom)	VDC (Nom)
24	1.10	330	2.7	3.8	5.6	8.8
25	2.13	488	3.9	5.5	7.7	12.2
26	2.90	544	4.5	6.4	9.0	14.2
27	5.27	760	6.1	8.6	12.1	19.2
28	9.15	1026	8.0	11.3	16.0	25.0
29	12.50	1146	9.4	13.2	18.7	30.0
30	20.70	1491	12.0	17.0	24.0	38.0
31	33.60	1904	15.0	22.0	31.0	48.0
32	53.50	2394	19.4	27.0	39.0	61.0
33	83.50	2970	24.0	34.0	48.0	76.0

[1] Continuously pulsed at stated watts and duty cycle
[2] Single pulse at stated watts (with coil at ambient room temperature 20°C)
[3] Other coil awg sizes available — please consult factory
[4] Reference number of turns

Specifications

Dielectric Strength	1000 VRMS
Recommended Minimum Heat Sink	Maximum watts dissipated by solenoid are based on an unrestricted flow of air at 20°C, with solenoid mounted on the equivalent of an aluminum plate measuring 3" square by 1/8" thick
Coil Resistance	±5% tolerance
Holding Force	Flat Face:5.24 lb (23.3 N) @ 20°C 60°:2.88 lb (12.8 N) @ 20°C
Weight	2.95 oz (83.6 gms)
Plunger Weight	0.71oz (20.1 gms)
Dimensions	Ø0.77" x 1.55" L (See page F29)

How to Order

Add the plunger number and the coil awg number to the part number (for example: to order a unit with a 60° plunger configuration without an anti-rotation flat rated for 12 VDC at 25% duty cycle, specify 195204-227.

Please see www.ledex.com (click on Stock Products tab) for our list of stock products available through our North American distributors.

SOLENOID, GUARDIAN A420-067074

Click on image to enlarge

Product Description | Customer Comments

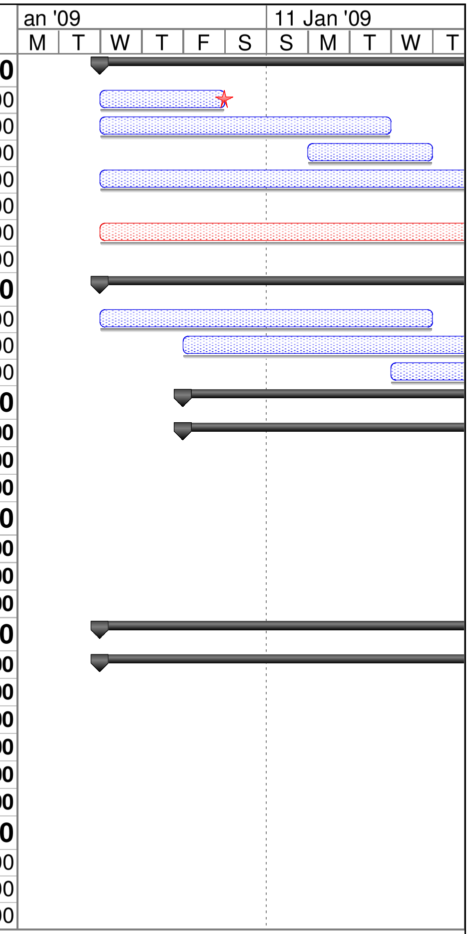
Guardian # A420-067074-00. 12Vdc, 44 Ohm coil. Push-type tubular solenoid with captive plunger. Solenoid body is 0.63" diameter x 1.17" long. 0.31" diameter, flatted, non-threaded bushing is 0.37" long. Plunger tip is 0.25" diameter. Plunger travels 0.17" when energized. 9" wire leads.

There haven't been any reviews for this item, you may be the first one to write a review.

APPENDIX E: GANTT CHARTS

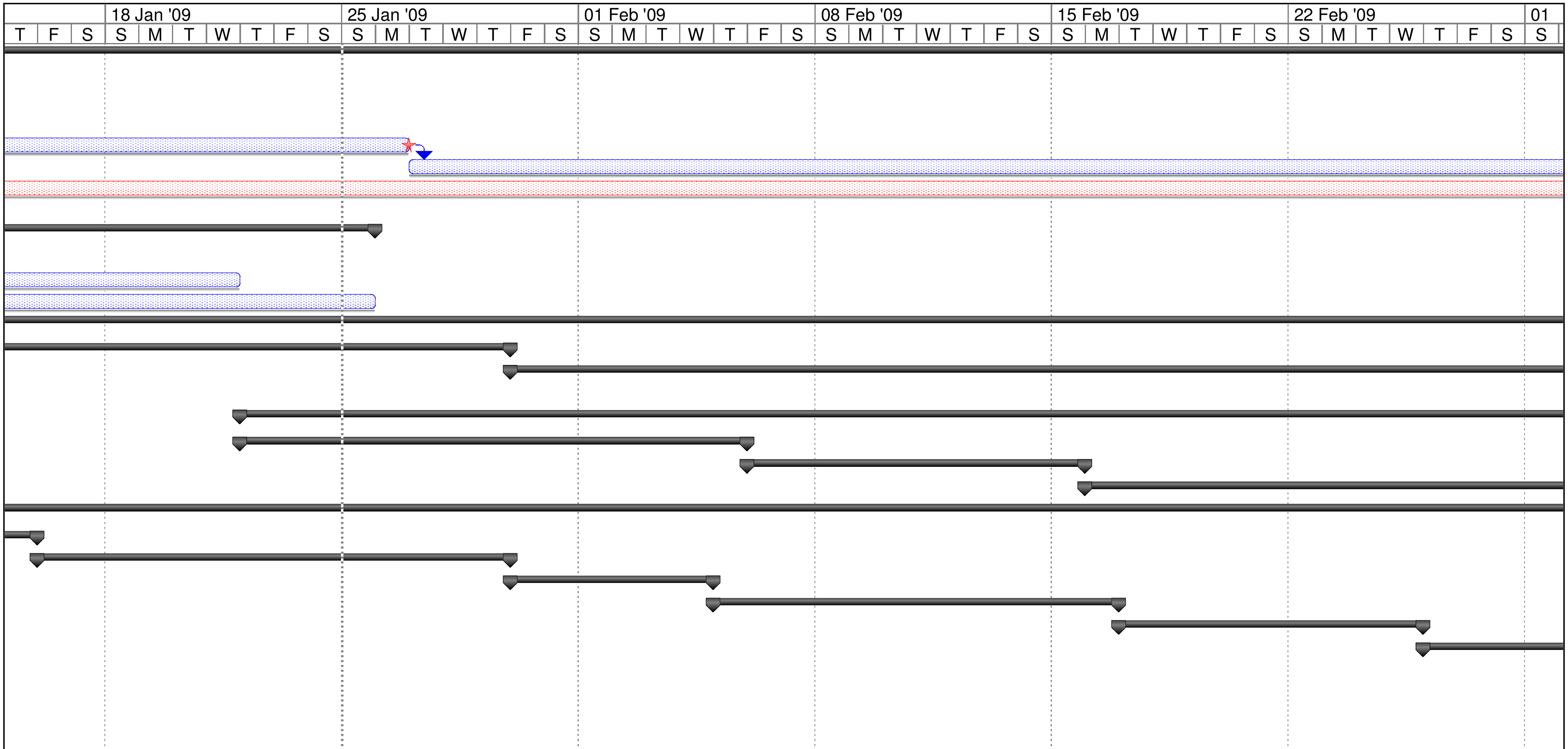
Milestones are indicated as red stars. Where milestones occur in the middle of a prolonged task, the whole task is shown in red. Please consult section 6.5 for specific dates. The first GANTT chart is for administrative, conceptual and integration tasks, followed by specific GANTT charts for the electromechanical, circuits, and microcontroller subsystems respectively.

ID		Task Name	Duration	Start	Finish	Cost
1		**Administrative**	**98 days**	**Wed 07/01/09**	**Tue 14/04/09**	**$715.00**
2		Finalize teams and assign subsystem responsibilities	3 days	Wed 07/01/09	Fri 09/01/09	$0.00
3		Purchase notebooks and course notes	7 days	Wed 07/01/09	Tue 13/01/09	$165.00
4		Obtain funds for design stores accounts and kits	3 days	Mon 12/01/09	Wed 14/01/09	$550.00
5		Work on design proposal	20 days	Wed 07/01/09	Mon 26/01/09	$0.00
6		Work on final report	78 days	Tue 27/01/09	Tue 14/04/09	$0.00
7		Update and submit notebooks	98 days	Wed 07/01/09	Tue 14/04/09	$0.00
8		Return kits and close store accounts	1 day	Mon 13/04/09	Mon 13/04/09	$0.00
9		**Conceptual**	**19 days**	**Wed 07/01/09**	**Sun 25/01/09**	**$0.00**
10		Understand RFP	8 days	Wed 07/01/09	Wed 14/01/09	$0.00
11		Brainstorm ideas and perform surveys	13 days	Fri 09/01/09	Wed 21/01/09	$0.00
12		Ask for clarification	12 days	Wed 14/01/09	Sun 25/01/09	$0.00
13		**Electromechanical**	**62 days**	**Fri 09/01/09**	**Wed 11/03/09**	**$125.00**
14		**Pre-Production**	**21 days**	**Fri 09/01/09**	**Thu 29/01/09**	**$50.00**
20		**Production**	**34 days**	**Fri 30/01/09**	**Wed 04/03/09**	**$60.00**
24		**Post-Production**	**7 days**	**Thu 05/03/09**	**Wed 11/03/09**	**$15.00**
27		**Circuits**	**40 days**	**Thu 22/01/09**	**Mon 02/03/09**	**$140.00**
28		**Prototyping**	**15 days**	**Thu 22/01/09**	**Thu 05/02/09**	**$80.00**
36		**Soldering**	**10 days**	**Fri 06/02/09**	**Sun 15/02/09**	**$60.00**
42		**Subsystem Integration and Debugging**	**15 days**	**Mon 16/02/09**	**Mon 02/03/09**	**$0.00**
47		**Microcontroller**	**56 days**	**Wed 07/01/09**	**Tue 03/03/09**	**$20.00**
48		**Preparation**	**9 days**	**Wed 07/01/09**	**Thu 15/01/09**	**$0.00**
54		**User Interface**	**14 days**	**Fri 16/01/09**	**Thu 29/01/09**	**$0.00**
63		**Mechanism Interface**	**6 days**	**Fri 30/01/09**	**Wed 04/02/09**	**$0.00**
67		**Data Structures and Storage**	**12 days**	**Thu 05/02/09**	**Mon 16/02/09**	**$0.00**
71		**Subsystem Integration and Testing**	**9 days**	**Tue 17/02/09**	**Wed 25/02/09**	**$20.00**
74		**Bonus Features**	**6 days**	**Thu 26/02/09**	**Tue 03/03/09**	**$0.00**
78		**Integration**	**36 days**	**Wed 04/03/09**	**Wed 08/04/09**	**$45.00**
79		System Integration and Testing - Basic Functionality	8 days	Wed 04/03/09	Wed 11/03/09	$15.00
80		System Integration and Testing - Required Functionality	14 days	Thu 12/03/09	Wed 25/03/09	$15.00
81		Final Debugging and Preparation for Presentation	14 days	Thu 26/03/09	Wed 08/04/09	$15.00



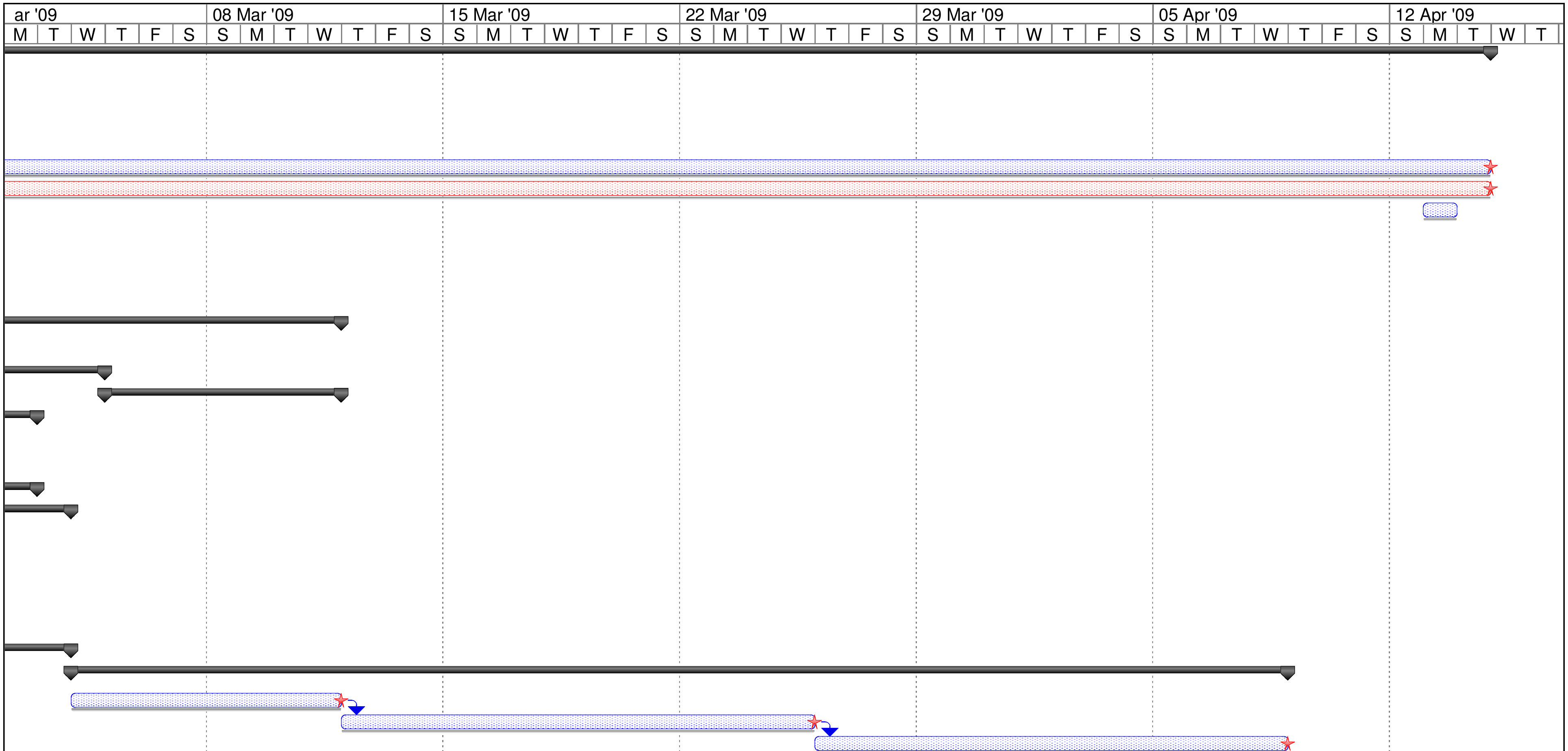
Project: GANTT
Date: Sun 25/01/09

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline



Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone	◇	Project Summary	
Milestone	◆	Rolled Up Progress		Group By Summary	
Summary		Split		Deadline	

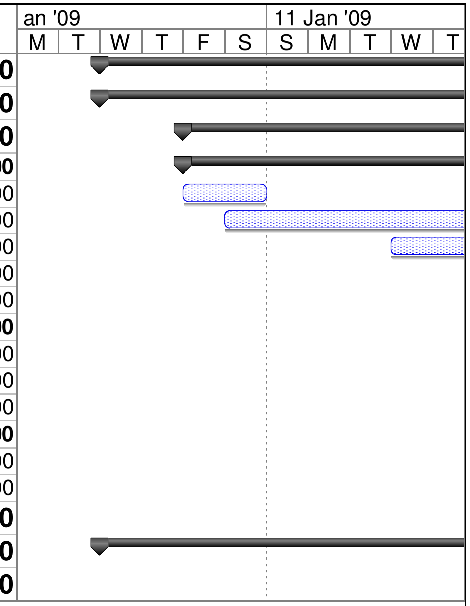
Project: GANTT
Date: Sun 25/01/09



Project: GANTT
Date: Sun 25/01/09

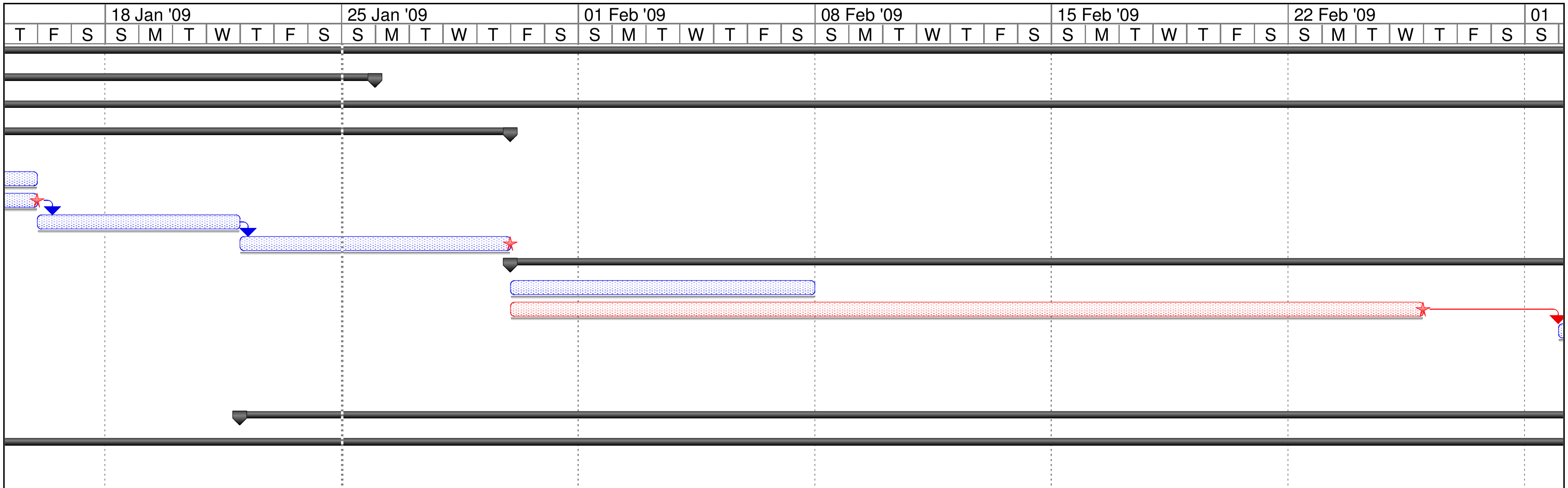
Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline

ID		Task Name	Duration	Start	Finish	Cost
1		**Administrative**	**98 days**	**Wed 07/01/09**	**Tue 14/04/09**	**$715.00**
9		**Conceptual**	**19 days**	**Wed 07/01/09**	**Sun 25/01/09**	**$0.00**
13		**Electromechanical**	**62 days**	**Fri 09/01/09**	**Wed 11/03/09**	**$125.00**
14		**Pre-Production**	**21 days**	**Fri 09/01/09**	**Thu 29/01/09**	**$50.00**
15		Outline functionality of each moving component	2 days	Fri 09/01/09	Sat 10/01/09	$0.00
16		Characterize the performance of various actuators	6 days	Sat 10/01/09	Thu 15/01/09	$30.00
17		Revise technical drawings based on dimensions of selected actua	2 days	Wed 14/01/09	Thu 15/01/09	$0.00
18		Test the power of solenoids without attachment to circuitry	6 days	Fri 16/01/09	Wed 21/01/09	$0.00
19		Complete "mule prototype	8 days	Thu 22/01/09	Thu 29/01/09	$20.00
20		**Production**	**34 days**	**Fri 30/01/09**	**Wed 04/03/09**	**$60.00**
21		Obtain moving parts and structural components	9 days	Fri 30/01/09	Sat 07/02/09	$60.00
22		Fabricate module one at a time	27 days	Fri 30/01/09	Wed 25/02/09	$0.00
23		Test functionality of each without attaching to circuitry	3 days	Mon 02/03/09	Wed 04/03/09	$0.00
24		**Post-Production**	**7 days**	**Thu 05/03/09**	**Wed 11/03/09**	**$15.00**
25		Module integration and testing	4 days	Thu 05/03/09	Sun 08/03/09	$0.00
26		Final troubleshooting	3 days	Mon 09/03/09	Wed 11/03/09	$15.00
27		**Circuits**	**40 days**	**Thu 22/01/09**	**Mon 02/03/09**	**$140.00**
47		**Microcontroller**	**56 days**	**Wed 07/01/09**	**Tue 03/03/09**	**$20.00**
78		**Integration**	**36 days**	**Wed 04/03/09**	**Wed 08/04/09**	**$45.00**



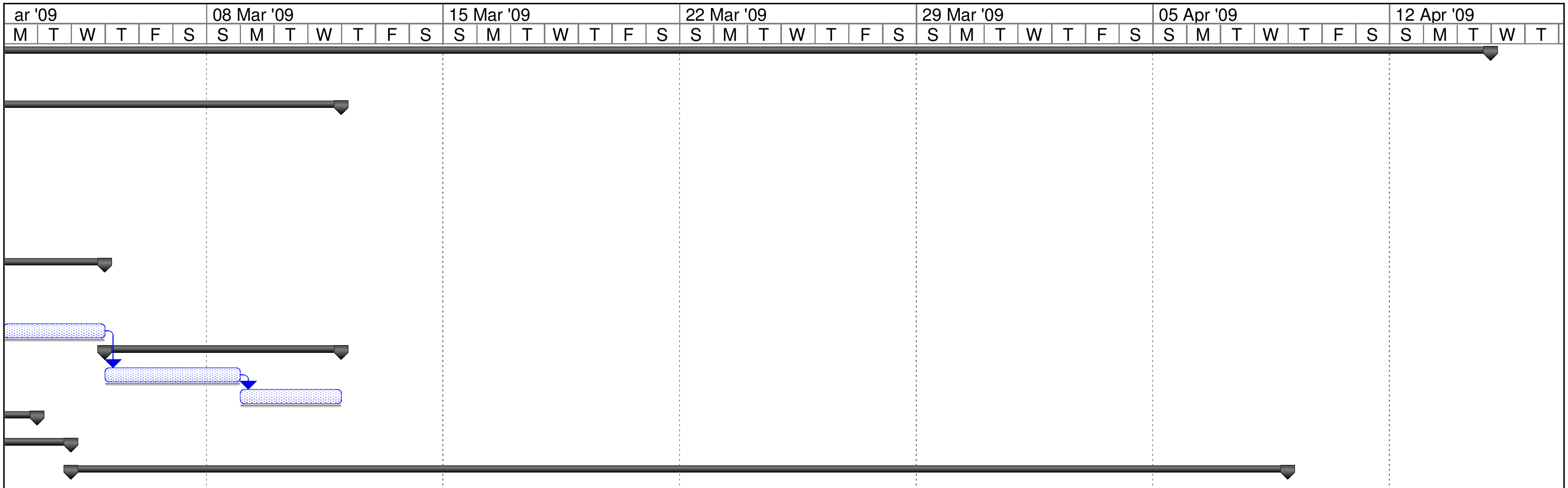
Project: GANTT-EM
Date: Sun 25/01/09

Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline



Project: GANTT-EM
Date: Sun 25/01/09

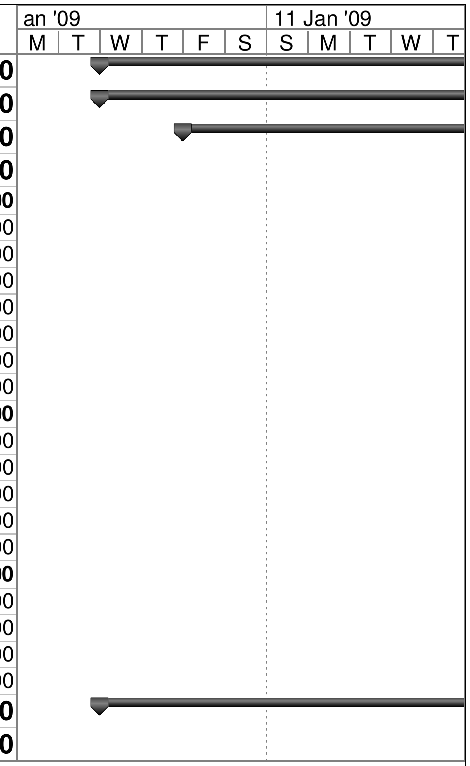
Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone	◇	Project Summary	
Milestone	◆	Rolled Up Progress		Group By Summary	
Summary		Split		Deadline	



Project: GANTT-EM
Date: Sun 25/01/09

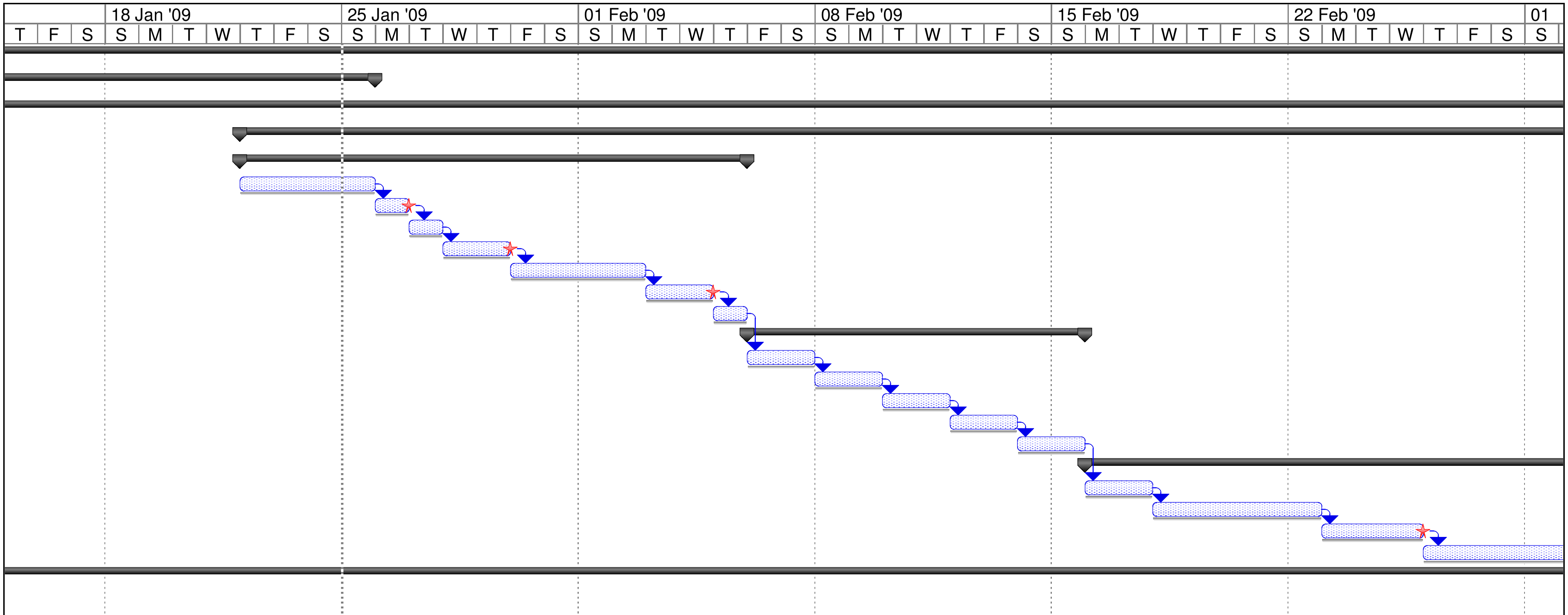
Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline

ID		Task Name	Duration	Start	Finish	Cost
1		**Administrative**	**98 days**	**Wed 07/01/09**	**Tue 14/04/09**	**$715.00**
9		**Conceptual**	**19 days**	**Wed 07/01/09**	**Sun 25/01/09**	**$0.00**
13		**Electromechanical**	**62 days**	**Fri 09/01/09**	**Wed 11/03/09**	**$125.00**
27		**Circuits**	**40 days**	**Thu 22/01/09**	**Mon 02/03/09**	**$140.00**
28		**Prototyping**	**15 days**	**Thu 22/01/09**	**Thu 05/02/09**	**$80.00**
29		Obtain required voltage from electromechanical member	4 days	Thu 22/01/09	Sun 25/01/09	$0.00
30		Design overall circuitry	1 day	Mon 26/01/09	Mon 26/01/09	$0.00
31		Explore possibilities of interference	1 day	Tue 27/01/09	Tue 27/01/09	$0.00
32		Design specific circuit diagrams	2 days	Wed 28/01/09	Thu 29/01/09	$0.00
33		Create circuit on protoboard for testing	4 days	Fri 30/01/09	Mon 02/02/09	$40.00
34		Finalize overall voltage, current and power requirements	2 days	Tue 03/02/09	Wed 04/02/09	$0.00
35		Obtain components and parts for soldering	1 day	Thu 05/02/09	Thu 05/02/09	$40.00
36		**Soldering**	**10 days**	**Fri 06/02/09**	**Sun 15/02/09**	**$60.00**
37		Driver Circuit	2 days	Fri 06/02/09	Sat 07/02/09	$5.00
38		Solenoid Circuit	2 days	Sun 08/02/09	Mon 09/02/09	$5.00
39		Testing with MC output signals	2 days	Tue 10/02/09	Wed 11/02/09	$25.00
40		Power-battery circuit	2 days	Thu 12/02/09	Fri 13/02/09	$25.00
41		Overall connections	2 days	Sat 14/02/09	Sun 15/02/09	$0.00
42		**Subsystem Integration and Debugging**	**15 days**	**Mon 16/02/09**	**Mon 02/03/09**	**$0.00**
43		Connecting circuits	2 days	Mon 16/02/09	Tue 17/02/09	$0.00
44		Convergence with Microcontroller	5 days	Wed 18/02/09	Sun 22/02/09	$0.00
45		Interfacing with Actuators	3 days	Mon 23/02/09	Wed 25/02/09	$0.00
46		Final Troubleshooting	5 days	Thu 26/02/09	Mon 02/03/09	$0.00
47		**Microcontroller**	**56 days**	**Wed 07/01/09**	**Tue 03/03/09**	**$20.00**
78		**Integration**	**36 days**	**Wed 04/03/09**	**Wed 08/04/09**	**$45.00**



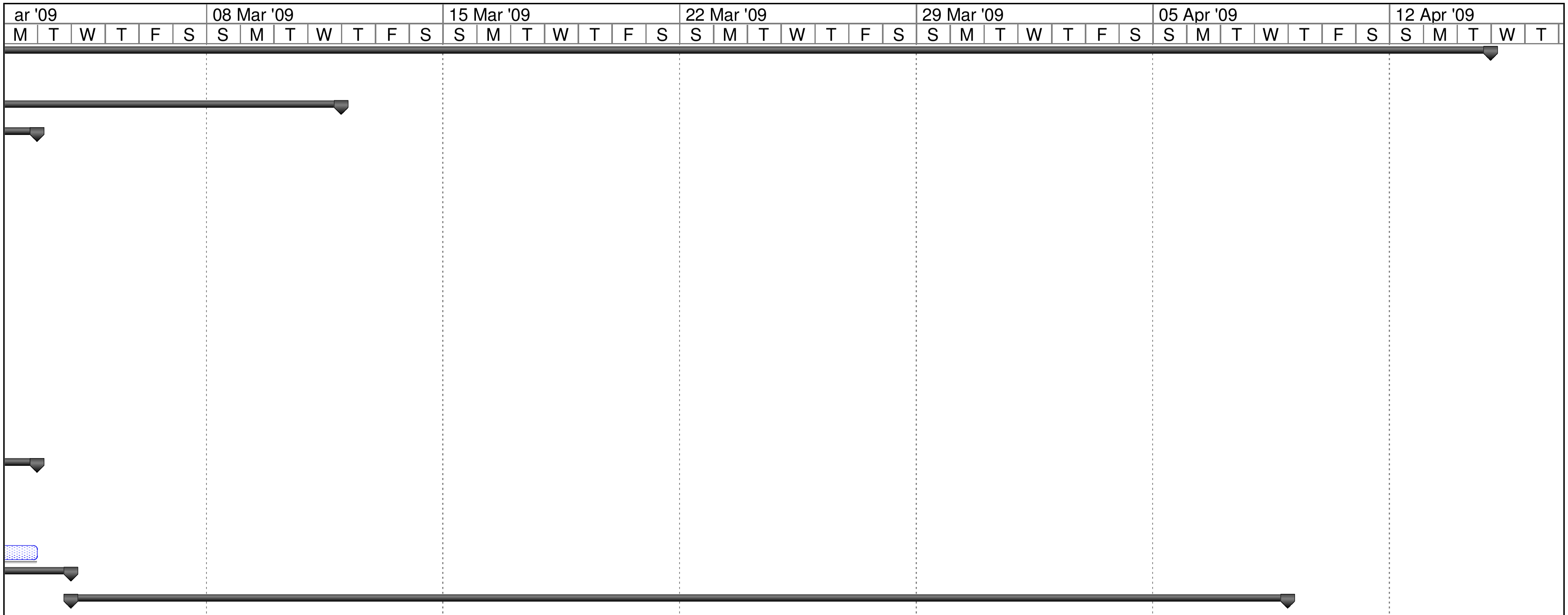
Project: GANTT-CCT
Date: Sun 25/01/09

Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline



Project: GANTT-CCT
Date: Sun 25/01/09

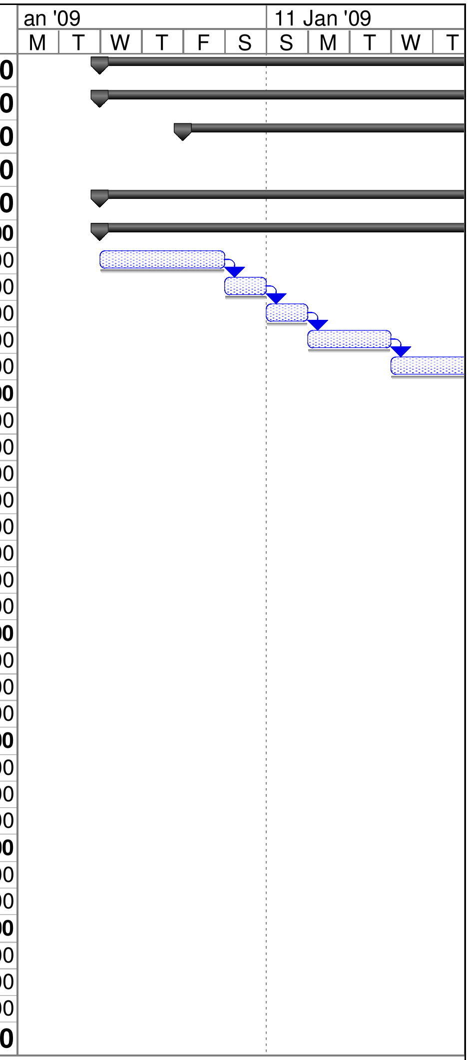
Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline



Project: GANTT-CCT
Date: Sun 25/01/09

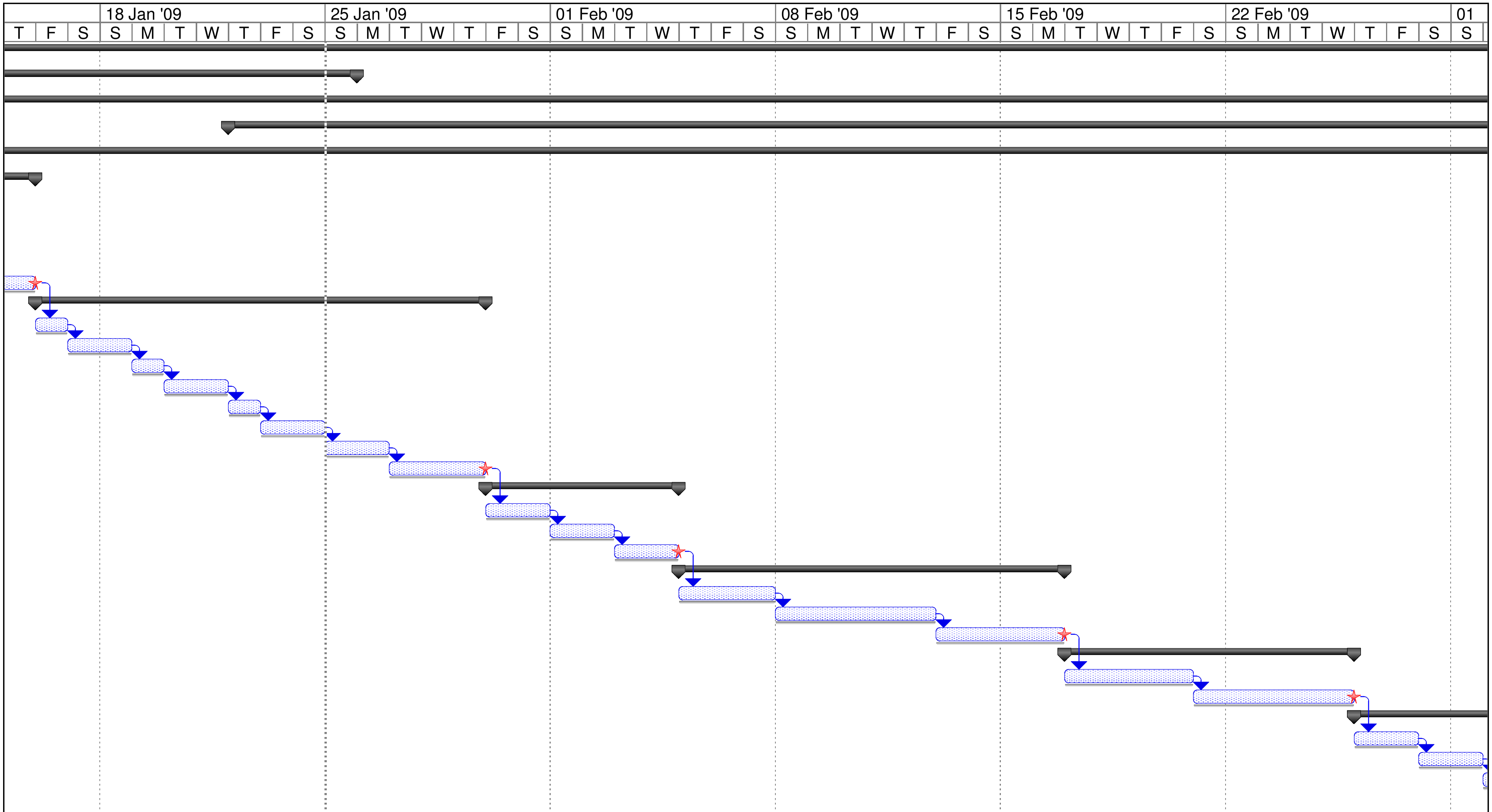
Task		Rolled Up Task		External Tasks	
Progress		Rolled Up Milestone		Project Summary	
Milestone		Rolled Up Progress		Group By Summary	
Summary		Split		Deadline	

ID	Task Name	Duration	Start	Finish	Cost
1	**Administrative**	**98 days**	**Wed 07/01/09**	**Tue 14/04/09**	**$715.00**
9	**Conceptual**	**19 days**	**Wed 07/01/09**	**Sun 25/01/09**	**$0.00**
13	**Electromechanical**	**62 days**	**Fri 09/01/09**	**Wed 11/03/09**	**$125.00**
27	**Circuits**	**40 days**	**Thu 22/01/09**	**Mon 02/03/09**	**$140.00**
47	**Microcontroller**	**56 days**	**Wed 07/01/09**	**Tue 03/03/09**	**$20.00**
48	**Preparation**	**9 days**	**Wed 07/01/09**	**Thu 15/01/09**	**$0.00**
49	Familiarization with PIC and peripheral interfacing	3 days	Wed 07/01/09	Fri 09/01/09	$0.00
50	Problem definition	1 day	Sat 10/01/09	Sat 10/01/09	$0.00
51	Flowchart creation	1 day	Sun 11/01/09	Sun 11/01/09	$0.00
52	Familiarization with MPLAB IDE	2 days	Mon 12/01/09	Tue 13/01/09	$0.00
53	Creation of pseudo-code	2 days	Wed 14/01/09	Thu 15/01/09	$0.00
54	**User Interface**	**14 days**	**Fri 16/01/09**	**Thu 29/01/09**	**$0.00**
55	Coding main template with basic definitions	1 day	Fri 16/01/09	Fri 16/01/09	$0.00
56	Coding functions for LCD interface	2 days	Sat 17/01/09	Sun 18/01/09	$0.00
57	Debugging and integrating LCD interface	1 day	Mon 19/01/09	Mon 19/01/09	$0.00
58	Coding functions for keypad interface	2 days	Tue 20/01/09	Wed 21/01/09	$0.00
59	Debugging and integrating keypad interface	1 day	Thu 22/01/09	Thu 22/01/09	$0.00
60	Coding functions for menu traversal	2 days	Fri 23/01/09	Sat 24/01/09	$0.00
61	Debugging and integrating menu traversal	2 days	Sun 25/01/09	Mon 26/01/09	$0.00
62	Integrating all user interface functions	3 days	Tue 27/01/09	Thu 29/01/09	$0.00
63	**Mechanism Interface**	**6 days**	**Fri 30/01/09**	**Wed 04/02/09**	**$0.00**
64	Code for Solenoids	2 days	Fri 30/01/09	Sat 31/01/09	$0.00
65	Code for pushbuttons	2 days	Sun 01/02/09	Mon 02/02/09	$0.00
66	Debugging and integrating mechanical interface	2 days	Tue 03/02/09	Wed 04/02/09	$0.00
67	**Data Structures and Storage**	**12 days**	**Thu 05/02/09**	**Mon 16/02/09**	**$0.00**
68	Coding functions for EEPROM storage	3 days	Thu 05/02/09	Sat 07/02/09	$0.00
69	Coding data structures and account information	5 days	Sun 08/02/09	Thu 12/02/09	$0.00
70	Integrating data structures and data storage	4 days	Fri 13/02/09	Mon 16/02/09	$0.00
71	**Subsystem Integration and Testing**	**9 days**	**Tue 17/02/09**	**Wed 25/02/09**	**$20.00**
72	Combine user and actuator interface	4 days	Tue 17/02/09	Fri 20/02/09	$10.00
73	Subsystem Integration and Debugging	5 days	Sat 21/02/09	Wed 25/02/09	$10.00
74	**Bonus Features**	**6 days**	**Thu 26/02/09**	**Tue 03/03/09**	**$0.00**
75	Date/Time	2 days	Thu 26/02/09	Fri 27/02/09	$0.00
76	Password Retrieval	2 days	Sat 28/02/09	Sun 01/03/09	$0.00
77	PC Interface 1	2 days	Mon 02/03/09	Tue 03/03/09	$0.00
78	**Integration**	**36 days**	**Wed 04/03/09**	**Wed 08/04/09**	**$45.00**



Project: GANTT-MC
Date: Sun 25/01/09

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline



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Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
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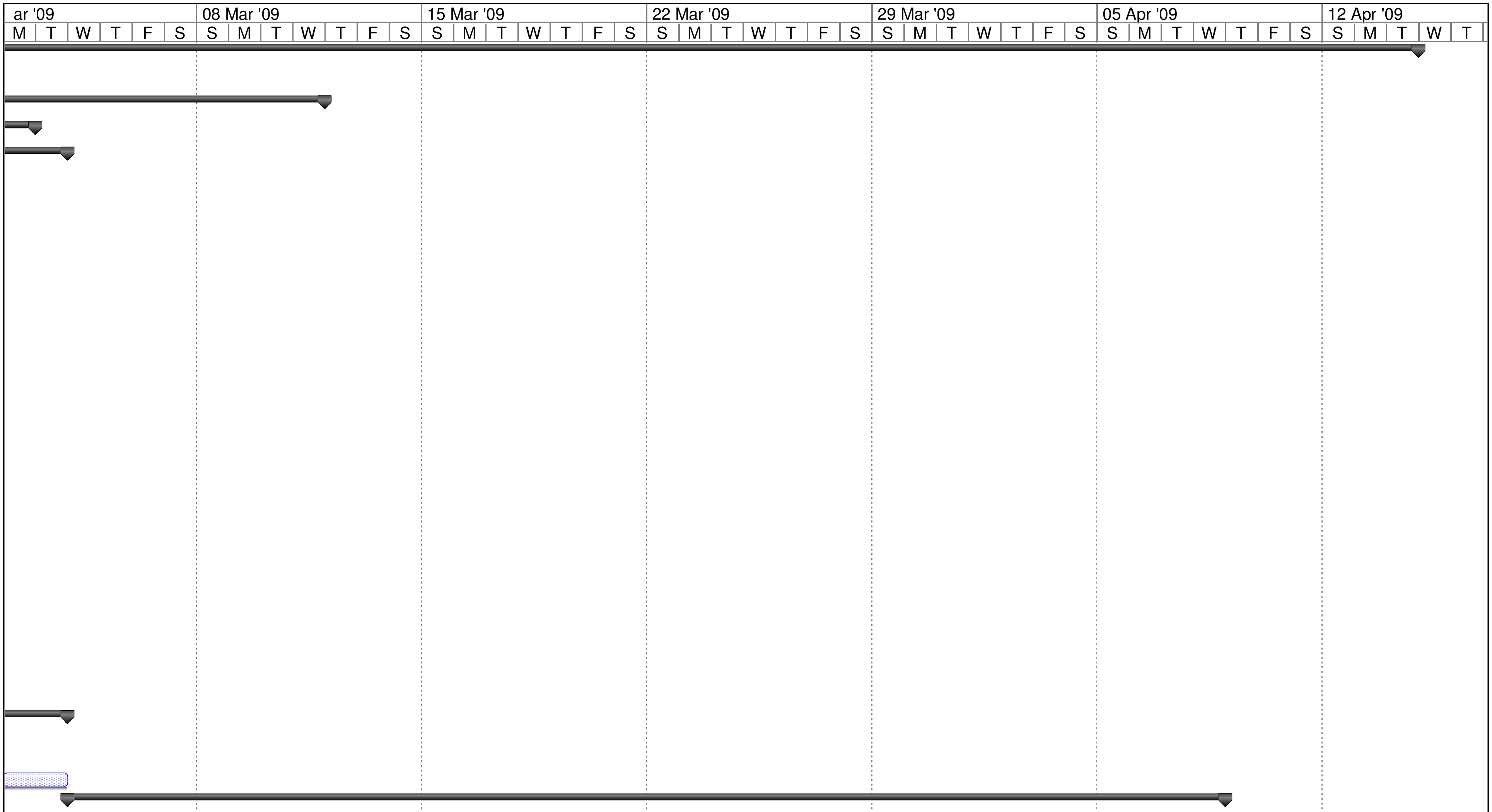

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