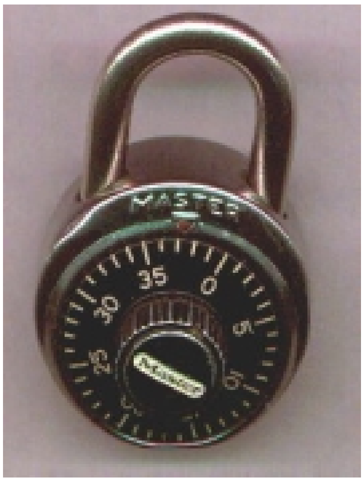
Final Project Report

The unLOCKer

SUMMARY:

The purpose of our final project is to unlock a Master Lock combination lock. ~~We will utilize a microphone to facilitate determining the combination.~~ We were not able to use sound to determine the combination because of the way the lock is built.



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1 PROJECT SUMMARY

The purpose of our final project is to unlock a Master Lock combination lock. ~~We will utilize a microphone to facilitate determining the combination.~~ We were not able to use sound to determine the combination because of the way the lock is built. We instead implemented an algorithm to reduce the number of possible combinations from 64,000 to 64.

☑ - Completed

☐ - Still needs to be done

1.1 Objectives

1) ☑ Figure out how to interface the motor with the combination lock
2) ☑ Learn how to step the motor
3) ☐ Precisely turn the dial between digits
4) ☒ Take in audio
   i) Filter noise
   ii) Determine the sound we are looking for (tumbler frequency)
5) ☑ Create an algorithm to solve combination
6) ☑ Output to the combination to the monitor dynamically
7) ☑ Find a way to open or test the lock latch
8) ☑ Prototype our machine parts

1.2 Expected Outcome

1) Match the interface so that it is snug, but does not bind the motor
2) Reuse code from last semester's robot arm team and modify it to use half steps
3) 360° / 40 digits = 9° per digit. Motor step = 3.6°
   - Thus, 5 half steps are needed per digit or 2.5 full steps
4) Utilize a microphone to monitor the sound coming from the lock
   - If we need amplification we will implement it
   - Analyze the sound we are looking for
5) Implement the control of the motor so that it successfully finds the combination
6) As we find the digits in the combination, output to the monitor
7) Use a push pull solenoid
8) Work with Mechanical Engineering Students (Interdisciplinary Consultants) to develop and build mechanical solutions to our design specifications
   a) Use SolidWorks CAD Software to model parts

1.3 Actual Outcome

1 ☑ Prototype our Motor to Dial Interface Rod

2 ☑ Reuse code from last semester's robot arm and modify it

3 ☑ Our code can precisely run the motor.

4 ☒ After taking apart many locks we found out that we can not use sound to determine the combination.

5 ☑ Researched ways to reduce the number of possible combinations. We were able to reduce it to 64.

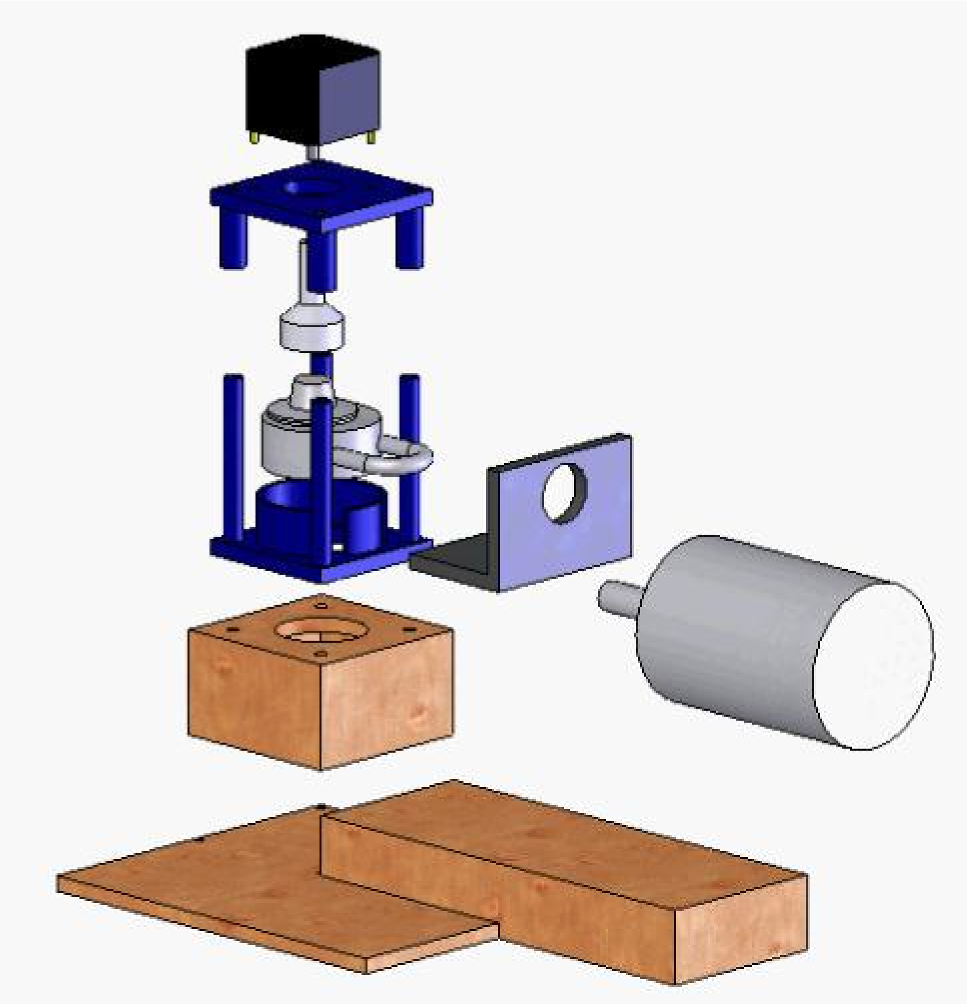
6 ☑ We print the combinations as we try them.

7 ☑ Used a solenoid to pull open the latch

8 ☑ Prototyped our parts (Dr. Liu paid the fee)

1.4 Mechanical Composition

See Appendix B for all parts and specs.



1.5 Audio Signal Processing

After analyzing the internals of the combination lock (see section 1.6.1), we determined that it would not be possible for us to use audio signal processing to figure out the combination. In essence, there are no sounds directly related to the combination.

1.6 Algorithm to reduce possible number of combinations

1.6.1 How a combination lock works

We spent a large amount of time researching how a combination lock works, and then focused our attention primarily on Master Locks because they are the most widely used, and they are all made in the exact same way. This allows us to capitalize on some of the ways things work to reduce the actual number of combinations.

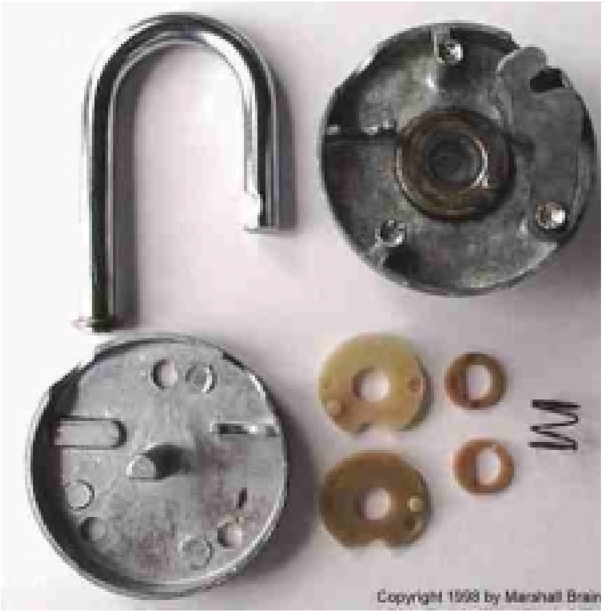


Figure 1.5.1 Internals of a Combination Lock [How] and **Figure 1.5.2** Master Lock [Master]

“There are three cams in a typical combination lock. In this lock (Figure 1.5.1) one of the cams is metal and is bonded directly to the turning face of the lock. The other two cams are plastic. There are two plastic spacers that fit between the cams.” [How]

Each cam has a large notch in it to allow the shackle to open, if all the cams are lined up. But how do the cams turn? “The middle and back cams have two pegs, one on each side. The front cam has one peg, on the back side of the cam. When the front cam is turned, its peg moves in a circular motion and, within one revolution, comes in contact with a peg on the middle cam. After it makes contact, it pushes the middle cam, so both turn. Within another revolution, the peg on the other side of the middle cam contacts a peg on the back cam, and starts pushing the back cam. Thus, within two revolutions of the lock dial, all three cams are turning.” [Master]

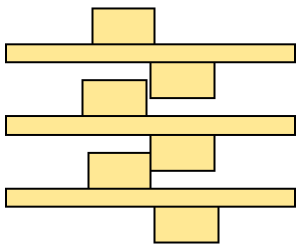


Figure 1.5.3 Lining up the Cams

“When the first number of the combination is reached, the notch on the back cam is lined up under the pawl. The user reverses the direction of the dial (starts turning to the left.) The peg on the front cam pulls away from the peg on the middle cam. The spacers hold the middle and back cams in place by friction. A spring, not shown in the picture on the left, ensures that the cams are pressed against the spacers. (The picture on the right shows the back and middle cams, back plate, and spring.)

The user turns the dial one revolution to the left. The peg on the front cam contacts the peg on the middle cam and both cams start to turn. The other peg on the middle cam pulls away from the peg on the back cam. The back cam does not move, so its notch remains lined up under the pawl. When the user reaches the second number of the combination, the notch on the second cam lines up under the pawl. The user reverses the dial direction once more (starts turning to the right.) The peg on the front cam pulls away from the peg on the middle cam. Both the middle and back cams remain in place with their notches lined up under the pawl. When the third number of the combination is reached, the deep notch on the first cam lines up under the pawl. The shackle may be pulled, the latch assembly will rotate on its shaft, and the shackle will release from the lock." [Master]

1.6.2 Resulting Algorithm

"To provide locks with all possible combinations, Master would need to use a much larger number of different cams. Not all 64,000 combinations are possible, due to mechanical constraints. However, it should be possible to make locks with 48,960 different combinations.

On its web site, Master claims to have 1,500 different combinations for the padlocks, so they must have reduced the number even further. *It appears that Master reduced the number of combinations in order to reduce the number of different cams it would need to manufacture and stock.* Using fewer cams would cut the manufacturing cost of the lock." [Master]

Because of the above facts and the fact that Master Lock created 11 false notches on the third cam, we are able to reduce the possible number of combinations to 64. Here's how.

Known: There are 12 notches in the third cam, and you can feel them by applying pressure to the shackle while turning the dial.

Application: Find these 12 notches and disregard any that are centered on a half of a number, ie 7.5 (7 of these are thrown away).

Known: There are four of these notches that are 90° apart.

Application: They can be disregarded as fake.

Thus: We have narrowed down the last number to one possible answer!

Possible combinations: 1600

Known: The first and last number mod 4 are equal to each other.

Application: We only have 10 possible first digits.

Possible combinations: 400

Known: If the first possible first number is 2 or greater, the first possible middle number is that number minus 2, or plus 2 if the first possible first number is less than 2. All the possible middle numbers are equal mod 4.

Application: We only have 10 possible middle digits.

Possible combinations: 100

Known: All three numbers have to each be more than two digits separate from each other because of the peg distribution.

Application: We can throw out two middle digits and two of each possible first digit combination. (see excel sheet: Masterlocks.xls)

Possible combinations: 64.

1.7 Budjet and Implementation

☐	**Parts and Tools**	**Quantity**	**Price (each)**
☑	Project Box	1	$4.00
☑	FPGA / EB63 (from class)	1	Provided
☑	LCD	1	Provided
☑	Proto Board	1	$5.25
☑	Serial Cable	1	Provided
	Power Supply		
☑	4.5 V for EB63	1	Provided
☐	12 V for motor	1	$10.00
☐	Amplifier (sound)	1	$6.00
☐	Molded rubber	1	$5.00
☑	Biphase stepper motor driver	1	$3.99
☑	Stepper Motor (1 backup)	2	$6.49
☑	Microphone	1	$1.49
☑	Master Locks	7	$2.50
☐	Push Pull Solenoid	1	$15.00
☐	Metal Rods (machined)	4	TBD
☐	Motor Mounting Plate (machined)	1	TBD
☐	Lock Mounting Plate (rapid-proto)	1	TBD
☐	Sound Chamber (rapid-proto)	1	TBD
☐	Motor to Dial Interface Rod (machined)	1	TBD
☑	Wire clippers / strippers	1	Provided
☑	Breadboard	1	Provided
☑	Soldering Iron	1	Provided
☑	Solder	1	Provided
☑	Flux	1	Provided
☑	Heat Shrink	1	Provided
☑	Wire Wrapping Wire	1	Provided
☑	Wire Wrapper	1	Provided
☑	Oscilloscope	1	Provided
		TOTAL:	$86.21

2 WAYS TO EXPAND ON PROJECT

Analyse tension

Have it figure out last number

3 TOOLS USED

Rapid Prototype Machine (courtesy of the Mechanical Engineering Dept at TAMU)

Solid Works CAD Software

Visual Studio (courtesy of the Computer engineering Dept at TAMU)

4 GLOSSARY

Master Lock
- Peg
- Cam
- Shackle: The U-shaped bar on the lock
- Body: The circular part of the lock the bar is attached to
- Dial: That part of the lock you rotate to enter the combination
- Right Turn: Clockwise turn
- Left Turn: Counterclockwise turn

Mechanical Words
- Drive Shaft

5 REFERENCES

(How) http://home.howstuffworks.com/inside-lock.htm

(Master lock) http://www.angelfire.com/ma4/masterlockcrack

(Unlocked) http://www.geocities.com/masterunlocked/ [Where we got the algorithm]

Adam and Ben

Interview How to reference a mechanical engineer

Jeff Stroh

Greg Zenner

Dr. Liu – tech assistance

6 APPENDIX A (PART LIST)

All of these parts are from JameCo.

MIC CART,1-12VDC,2PIN LEADS
SEN:-64db,20HZ TO 10KHZ
Jameco #: 140986

Omnidirectional Electret Condenser Microphone Cartridge

Applications:

- Tape recorders, intercoms, hearing aids, telephone and answering devices, sonic controlled toys and sensors
- Modems for computers
- Used for recording, testing and monitoring
- Type: CRM919
- Sensitivity: -64 ± 3dB
- Impedance: 1k ohm ± 30%
- Frequency(Hz): 20-10,000
- Max. Op. Voltage (VDC):12V
- Standard Op. Voltage (VDC): 3.0V
- Current (Max.): 0.8mA
- Sensitivity Reduction: -3dB @ 3V
- S/N Ratio: >40dB
- Terminals:Solder Pad
- Size: .90"H x .39" Dia.

https://www.jameco.com/webapp/wcs/stores/servlet/ProductDisplay?langId=-1&storeId=10001&catalogId=10001&productId=121507

Stepper Motor

- Excellent for precision control
- Can be operated in forward/reverse mode
- Excellent torque/size ratio
- Wide variety of supply voltages
- Data sheet included
- P/N 25216(MC3479P) biphase stepper motor driver can be used to operate stepper motor
- Check for compatible power supplies
- Step angle: 3.6 degrees
- No. of phases: 2
- Drive System: bipolar
- Voltage(VDC): 12
- Phase resistance (Ohms): 25-Current (mA): 480

- Phase Inductance (mH) 31
- Detent torque(g-cm): 80
- Holding Torque(g-cm): 600
- Mounting hole space digonal(in.): 1.73
- Mounting hole (in.) .11
- Shaft diameter (in.): 0.197
- Shaft length(in.): 0.43
- Motor Diameter(in.): 1.66
- Motor height (in.)1.31
- Weight: 0.55 lbs.

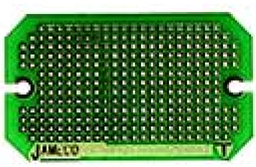
http://www.jameco.com/webapp/wcs/stores/servlet/CategoryDisplay?storeId=10001&catalogId=10001&langId=-1&categoryId=11017

IC,MC3479P
Jameco #: 25216

MC3479P IC
Motorola Type Linear Series

- Biphase stepper motor driver
- Dual In-line Package
- 16-pins

https://www.jameco.com/webapp/wcs/stores/servlet/ProductDisplay?langId=-1&storeId=10001&catalogId=10001&productId=116450



PROTOTYPE BUILDER,1.6"x2.7"

Jameco #: 105099

General Purpose Prototyping Board

Prototype boards with punched holes are convenient, economical tools for assembling circuit components and trying cost-effective alternatives to custom designs.

- 0.062" board thickness
- 0.1" hole spacing
- 0.08" pad size
- Plated through pads are double-sided
- PCB material epoxy glass
- Size: 1.60"W x 2.70"L
- Fits enclosure(s): P/N 18921
- Circuit pattern: pad per hole
- Hole pads: single-sided
- Number of holes x diameter: 288 x 0.035"
- Power/ground busses: none
- Connector I/O or edge: none
- Number of mounting holes x diameter: 2 x .115"
- Weight: .02lbs.

https://www.jameco.com/webapp/wcs/stores/servlet/ProductDisplay?langId=-1&storeId=10001&catalogId=10001&productId=119792

LINEAR SOLENOID
12 / 24 VDC - 39 OHM COIL

(MOT) A420-066266-00
Guardian linear solenoid pulls 1-1/2" stroke at 64 oz. with 1/2" diameter plunger. End of plunger tapped for #8 screw. Body 2-3/4" x 1-1/2" diameter. Threaded neck is 1" diameter. Nut not included.

Miscellaneous Parts:

Project Box

FPGA / EB63 (from class)

LCD

Breadboard

Serial Cable

Power Supply (4.5 V for EB63 and 12 V for motor)

Amplifier (sound)

Molded rubber

7 APPENDIX B (CODE)

Source Code

8 APPENDIX C (MECHANICAL COMPOSITION)

Sheets and images

9 APPENDIX D (REFERENCE MATERIAL)

Data sheets