2 DIGIT PROGRAMMABLE COMBINATION LOCK FOR THE ZEN 10C1**-A-V1

Programmed by Brian Peters
12/07/2011

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2 DIGIT COMBINATION LOCK
FOR THE ZEN 10C1**-A-V1
OPERATION MANUAL

Written by Brian Peters
12/07/2011

- SETTING UP THE LOCK -

1. Use the Zen Support Software to transfer the 2 Digit Combination Lock software program onto your Zen Programmable Relay.

2. Set the Zen hardware to RUN MODE.

3. At this point, the screen will go blank. This is an ideal time to power down the unit and hook up your hardware according to the wiring diagram.

4. After wiring up all your hardware, turn on the Zen. The screen on the Zen should be blank at this point. If the menu is being displayed, hit the ESC button. Once the screen is blank, the Zen is now awaiting your input for the 2 digit passcode you wish to program into the unit.

6. Using the four numerical buttons on the face of the Zen, enter any two digits that you wish to function as the passcode for this lock. (This can be undone later using the hardwired reset switch.) The digits will appear on the screen as you type them.

7. After you have entered two digits, hit ALT to save them into the memory of the PLC. (If you make a mistake while entering the digits, you can clear your entry by hitting the DEL button at any point before saving the code.)

8. After the digits are saved, the screen will go blank. The PLC is now locked and awaiting a passcode attempt in order to unlock.

- USING THE LOCK -

1. After a password has been set and the unit is now locked and running, the screen should be blank. If the PLC menu is displayed, hit the ESC button to clear the screen. Using the four numerical buttons, enter the same password that is saved into the PLC. The digits will appear on the screen as you type them.

2. After you have entered the correct two digits, hit ALT and the unit will unlock, as well as display the green "unlocked" light. (If you make a mistake while entering the digits, you can clear your entry by hitting the DEL button at any point before submitting the passcode attempt.)

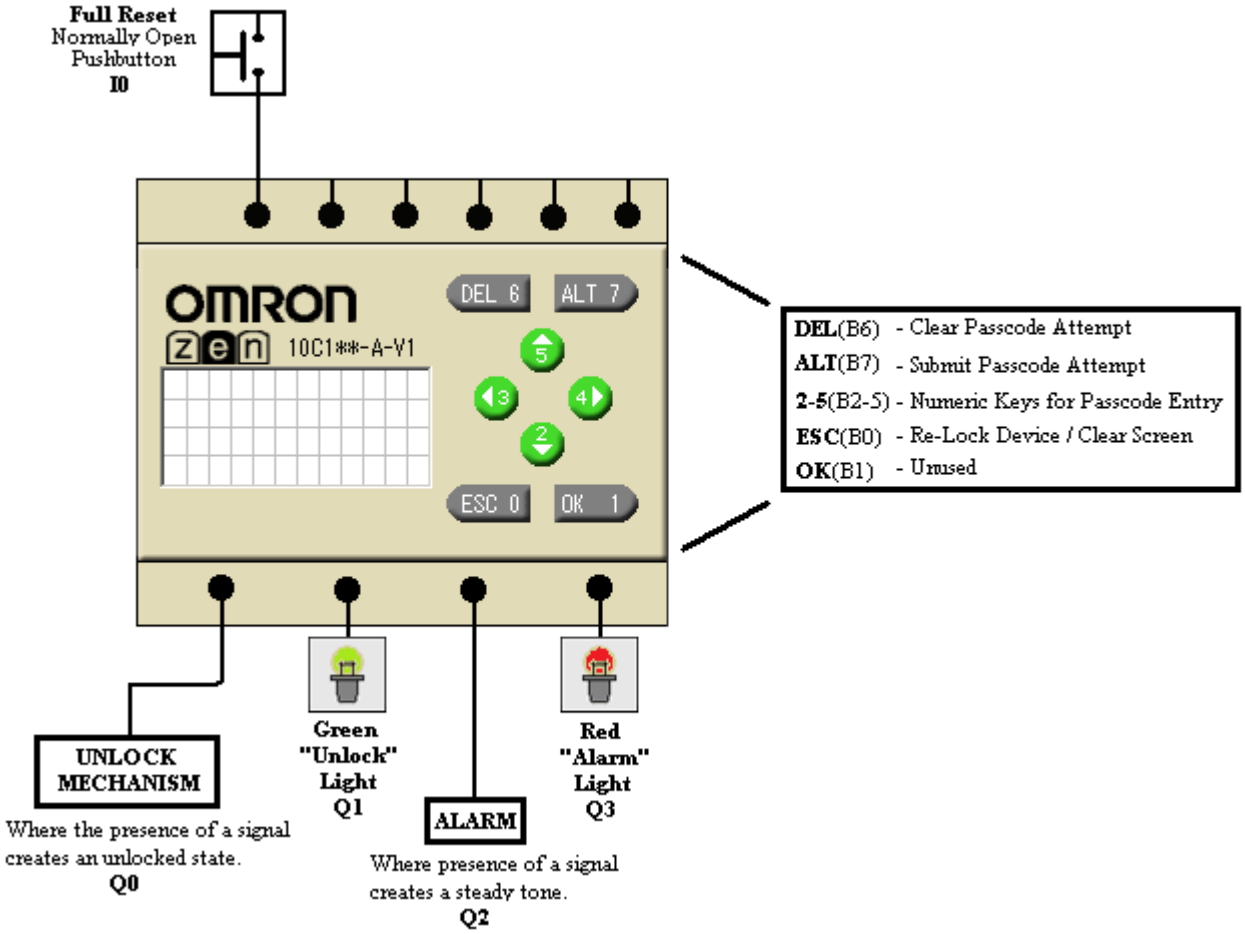
3. To re-lock the unit, simply hit the ESC button twice. (Once to lock the unit, and then again to clear the Zen menu.)

4. If the wrong passcode is submitted, the alarm light will flash once and the screen will clear and await another attempt. After the wrong passcode is submitted three times, the unit will go into "lockdown mode" and display the word "LOCKED" across the screen, while pulsing an audible alarm and alarm light. The Zen will stay in "lockdown mode" until it is reset using the hardwired reset button.

- RESETTING THE LOCK -

1. To reset the saved passcode or take the unit out of lockdown mode, simply press the hardwired reset button and the unit will return to its first state, awaiting entry to save a new passcode. See Step 4 under "Setting Up The Lock."

HARDWARE DIAGRAM



WIRING

I0: Normally Open button for Full Reset
Q0: Unlock (where presence of a signal creates an unlocked state)
Q1: Green "Unlock" Light (where presence of a signal illuminates light)
Q2: Alarm (where presence of a signal creates a steady tone)
Q3: Red "Alarm" Light (where presence of a signal illuminates light)

SPEC SHEET

INPUTS: (8)

1 Hardwired Reset Button (I0)
4 Numerical Buttons (B2-B5)
1 Submit Button (ALT - B7)
1 Clear Entry Button (DEL - B6)
1 Re-Lock Button (ESC - B0)

OUTPUTS: (5) (or 13 bits, if you're counting the display)

1 Unlocking Mechanism (where presence of a signal will create an unlocked state) (Q0)
1 Green "Unlock" Light (Q1)
1 Alarm (where presence of a signal will create a steady tone) (Q2)
1 Red "Alarm" Light (Q3)
1 Display (9 Different Display Messages)

ADDITIONAL RESOURCES: 34 Bits

12 Work Bits
11 Hold Bits
6 Counters
3 Timers
2 Comparator Bits

95 Rungs (1 Free)

FREE RESOURCES:

0 Outputs
5 Inputs (I1-5)
1 Face Button (B1 - OK)
1 Work Bits (M1)
5 Holding Bits (H5,6,C,D,E)
13 Timers (T0-C)
6 Counters (C6-F)
7 Display Outputs (D9-F)

1 Free Rung (#95)

Tested on Programmable Relay Zen 10C1AR-A-V1

2 DIGIT COMBINATION LOCK
FOR THE ZEN 10C1**-A-V1
TECHNICAL DOCUMENTATION

Written by Brian Peters
12/07/2011

The 2 Digit Combination Lock program works as follows:

GENERAL FUNCTION (PASSWORD VERIFICATION):

Two digits are saved in a bank of four holding bits (H1-H4. Rungs 28-35) Since there are only four possible digits (based off the numerical buttons of 2-5 on the faceplate of the Zen), the numbers are able to be stored using the binary equivalents of 0-3 (00, 01, 10, 11) and require two bits each.

After a password is saved in the holding bits, a password attempt is saved in counters functioning as surrogate work bits (able to represent 0 or 1 by "triggering" when they are ticked to 1.) (C1-C4. Rungs 53-60) This was done as part of optimization to make the program possible with the limited resources of the Zen.

After the password is submitted, the bits stored in holding bits H1-H4 are compared with the bits stored in counters C1-C4, and if there is a 100% match, Output Q0 is latched on, effectively opening the lock and setting the "unlocked" state in the program. (Rungs 62-72)

The ESC button (B0) resets Output Q0, and effectively re-locks the unit.

LOCKDOWN

Every time a submission does not match, holding bit Hf is used to tick the "3 failed attempts" counter C5 forward one. When C5 reaches 3, it goes off, enabling the alarm mechanisms and effectively disabling rungs 20-27, which allow keycode entry.

HARDWIRED RESET

The hardwired reset button I0 resets the state of the "3 failed attempts" counter C5, resets the numeric place counter C0, resets the password submission bits, and resets the password attempt bits.

NUMERIC PLACE HOLDING AND INTERFACE FUNCTIONALITY

Most of the numeric entry interfacing is governed by counter C0, which is capable of indicating one of three states: No numbers have been entered, one number, or two numbers. Digital comparators are used throughout the program to react to the place stored in C0 in order to allow or not allow certain things to happen. (For example, the bits that store the second digit in rungs 32-35 will only record the input if C0 is at 1, signifying that one digit has already been entered, but two have not.)

PLACE HOLDING VS. RECORDING ENTRY

A large amount of the programming of the combination lock enables the differentiation between the functions of place holding changes after button presses vs recording entry of the button presses themselves. For example, if both were governed by the same control system, the depression of a button would record the number in the first digit bank while simultaneously moving the place forward and recording the same number in the second bank, possibly not even recording the first digit at all.

This program incorporates a system of "traps" to effectively cause the onset of the button press to record the bit, while lifting a finger off the button causes it to move forward in place, thus

isolating the two systems. Rungs 0-7 latch a workbit (M2-5) for the button first pressed while rungs 28-31 save the appropriate bits to represent the number for the first digit. Rungs 16-19 create a workbit (M0) which is reflective of any and all button presses, which disables the ability of the latched workbits (M2-5) to move the place counter forward in rungs 20-27. When the first button is depressed, M0 allows rungs 20-27 to pass through and the latch remains to count forward on the place counter in rungs 20-27. As soon as the place counter counts forward, rungs 0-7 are disabled with all latches broken and rungs 8-15 are enabled.

A differentiating system was initially added to prevent a latch from ticking C0 in rungs 20-27, but was removed during optimization as no bugs were creatable in software simulation or hardware testing. The slightest delay in response of workbit M0 could hypothetically cause a bug though, whereas the first digit would be recorded and displayed as a 2 (signifying no bits were able to be triggered.)

POTENTIAL FOR FUTURE DEVELOPMENT:

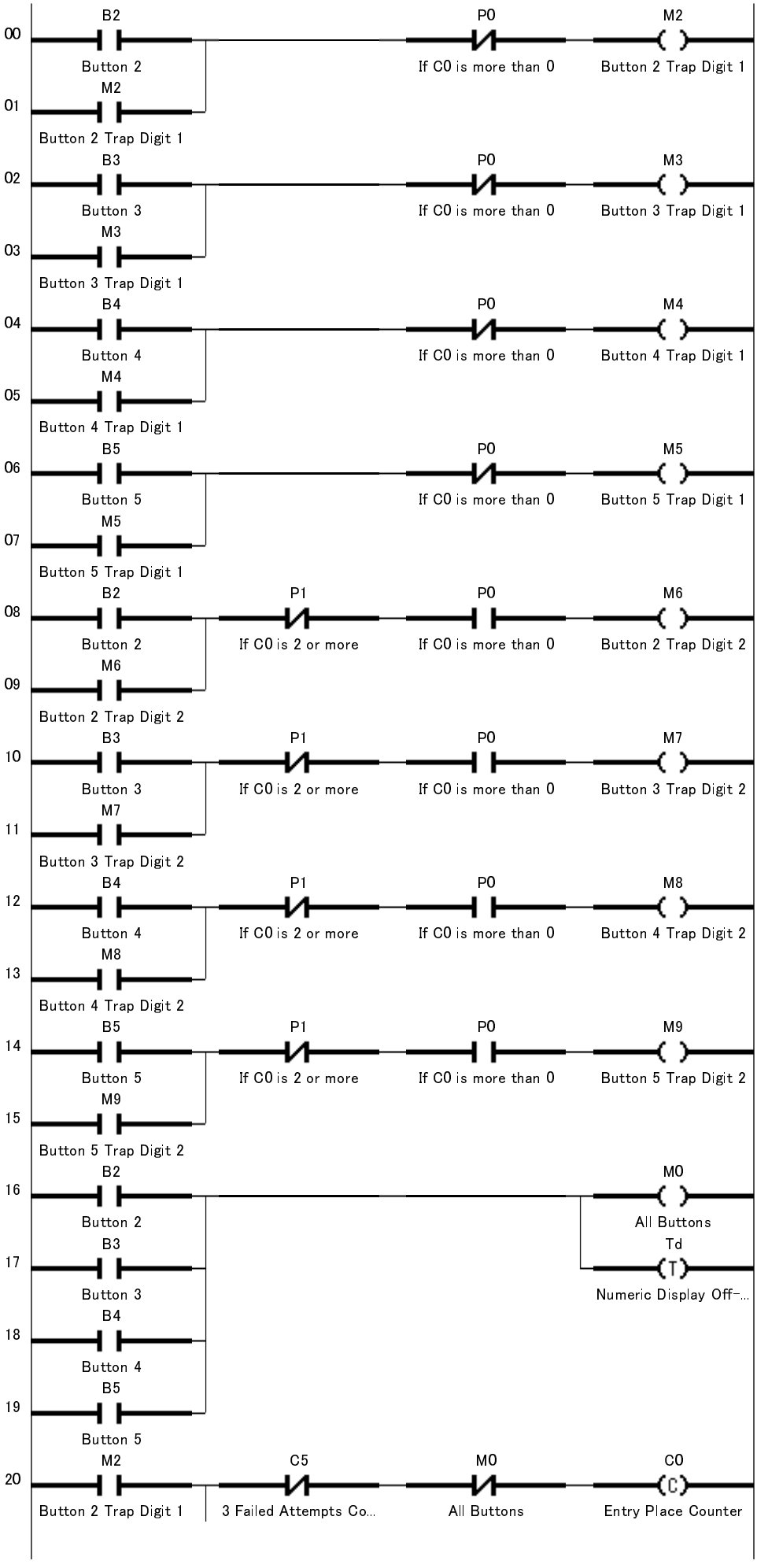
The current program, after optimization, occupies 94 rungs of Zen programming. The current limitation of 95 rungs for the Zen is the primary limiting factor in further development of the combination lock. With approximately 140-160 lines, it would be possible (with all the other resources untouched) to create a 3 digit combination lock (using remaining work bits and counters standing in for work bits.)

If additional rungs AND additional work bits were made available, the banks that store the password attempts could be expanded to accomodate a wider range of digits in the password, with four bits required for hexadecimal or decimal function.

During development, it was discovered that it was impossible to disable the hardwired functions of the ESC and OK buttons. (If used, the OK button will function simultaneously as the "enter" button in the onboard menu on the Zen, while the ESC button will open/close the I/O monitor.) Initially the OK button was implemented as the "enter" function, while the ALT button was implemented as the "save" function, but were retroactively combined into the same "submit" function for the ALT button. For lack of buttons, the ESC button was still included, as it did not inhibit.function or present any possible bugs at this point.

KNOWN BUGS

Under some circumstances, while the unit is in lockdown mode, depressing buttons may store a digit in the password submission for after the unit is reset using the hardwired reset button. A number would then be displayed after the reset, which can be erased using the DEL button. This is due to an error in the reliability of the non-traditional programming logic in rungs 38-46. This problem could be alleviated by replacing the outputs in rungs 38-46 with one work bit, and then using that workbit as an input for the current outputs of rungs 38-46. Unfortunately, this would require 8 more available rungs in the program.

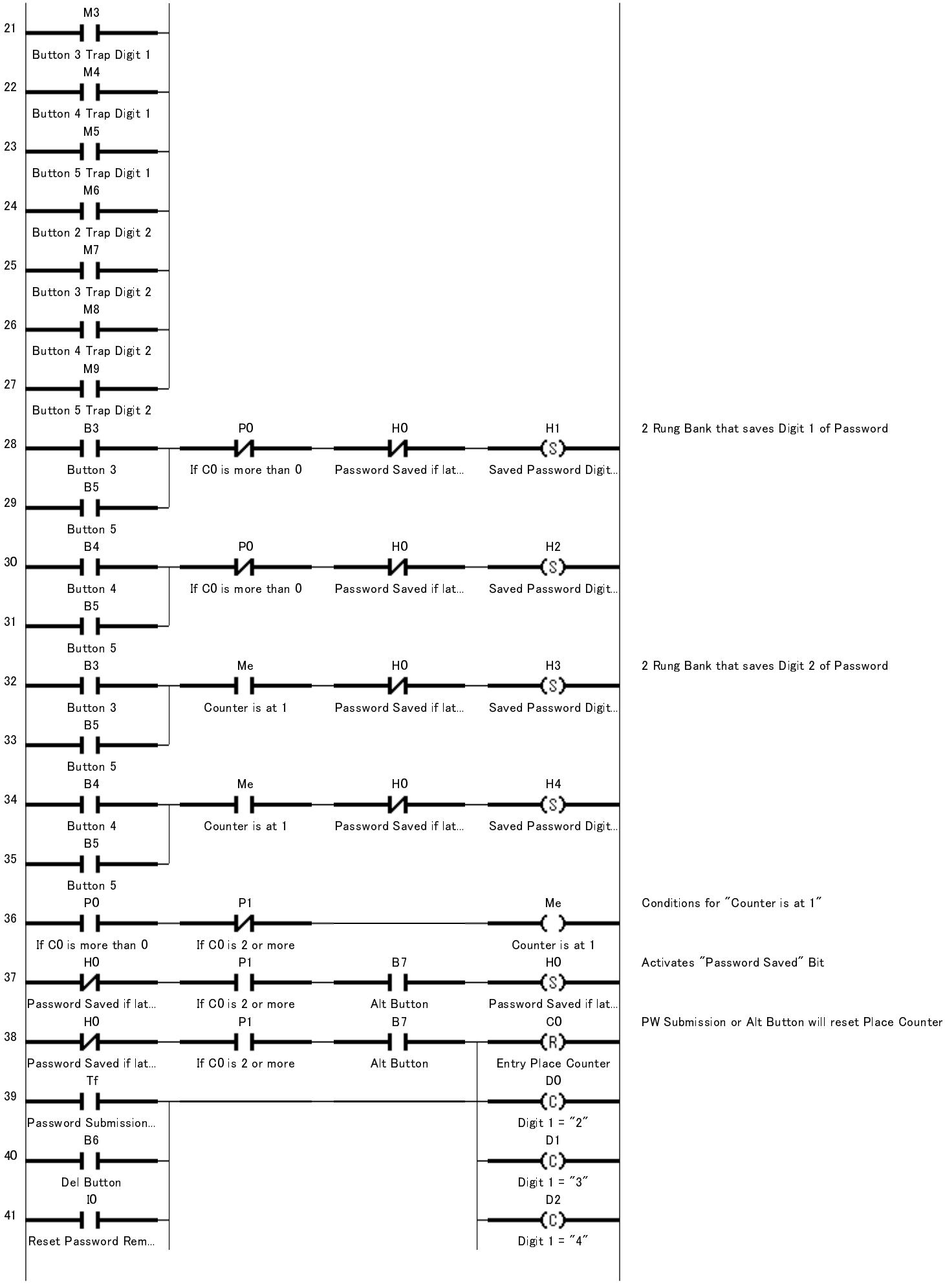


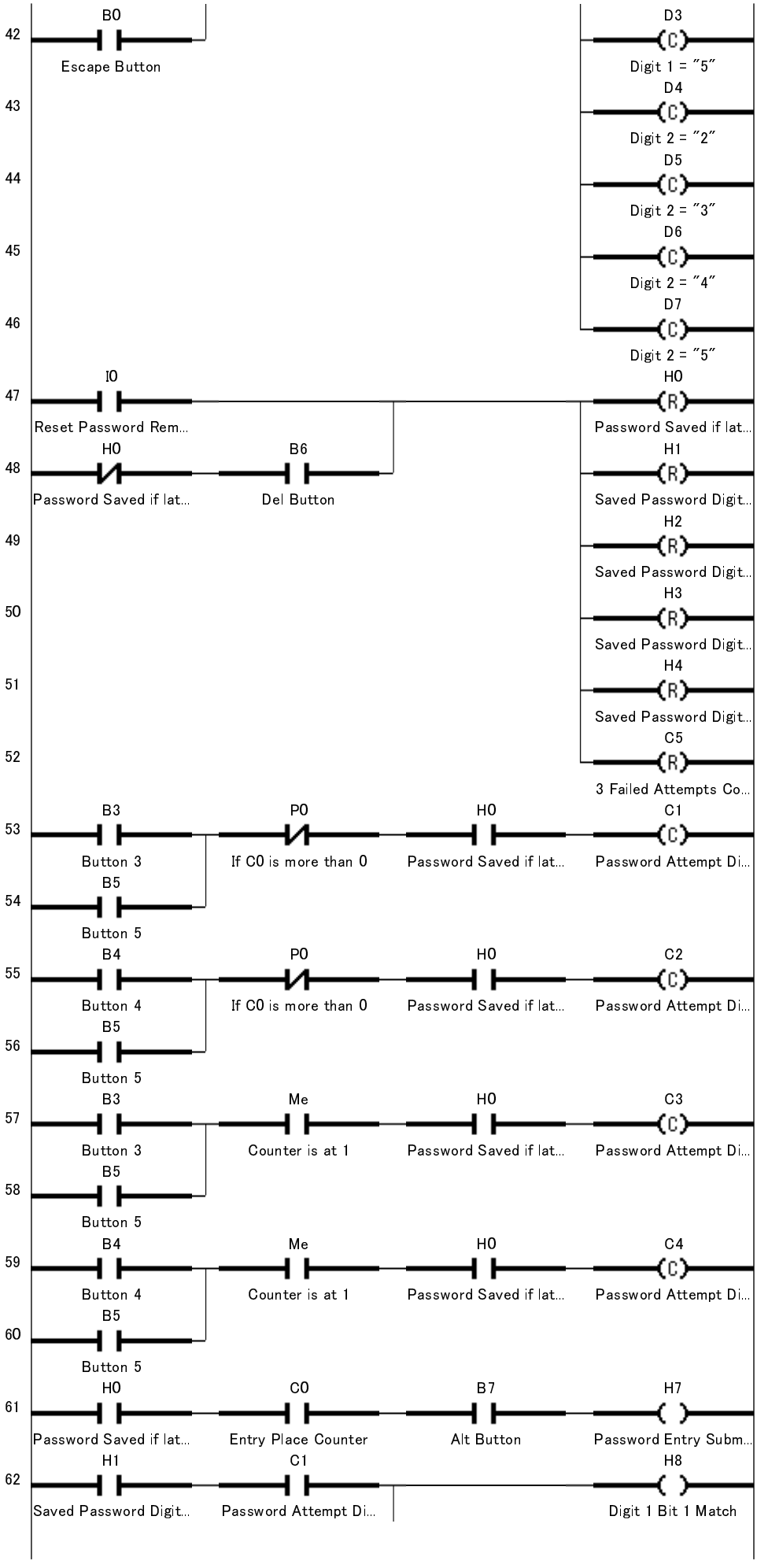
Bank of Button Traps for Digit 1 to De-Jitter

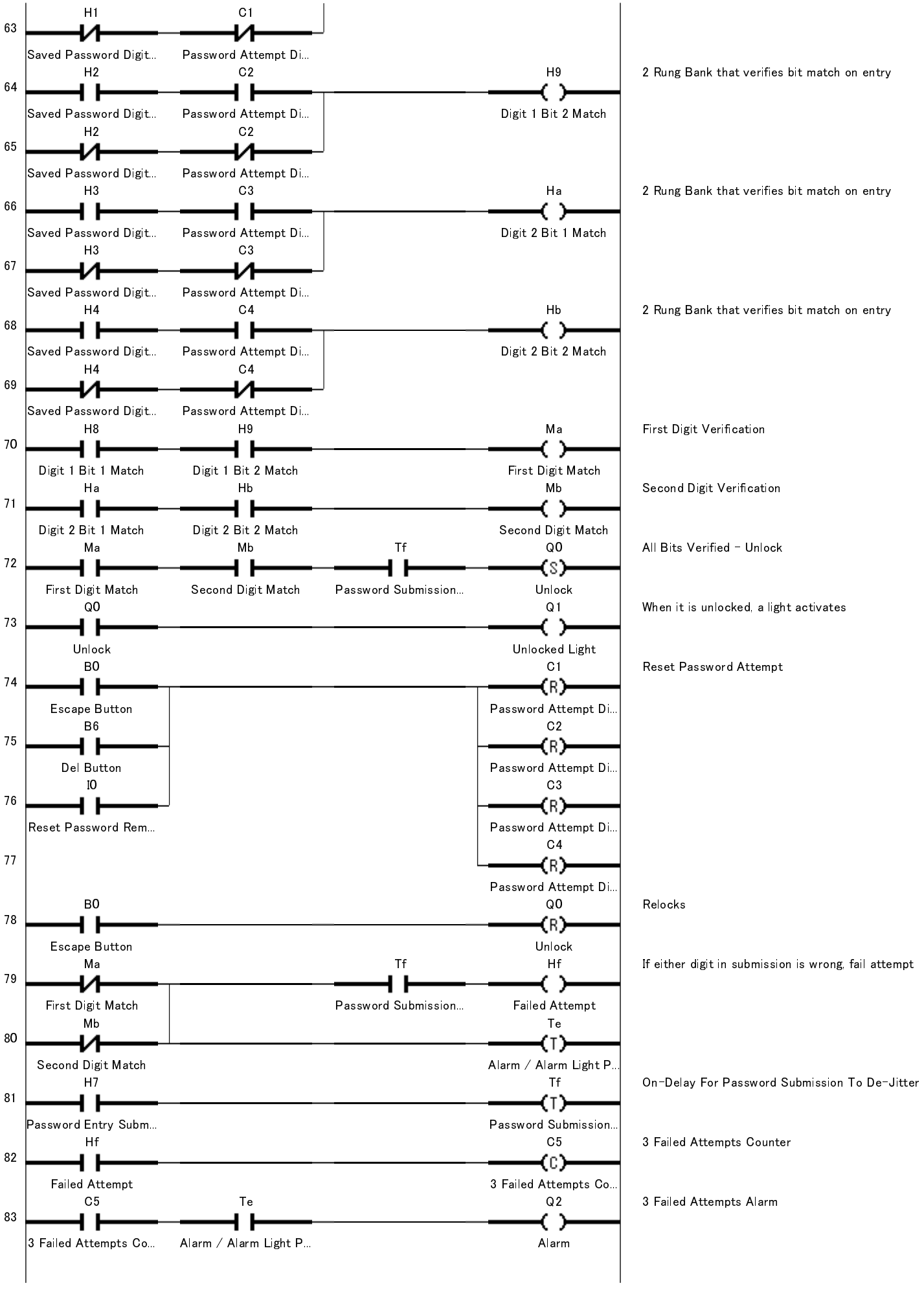
Bank of Button Traps for Digit 2 to De-Jitter

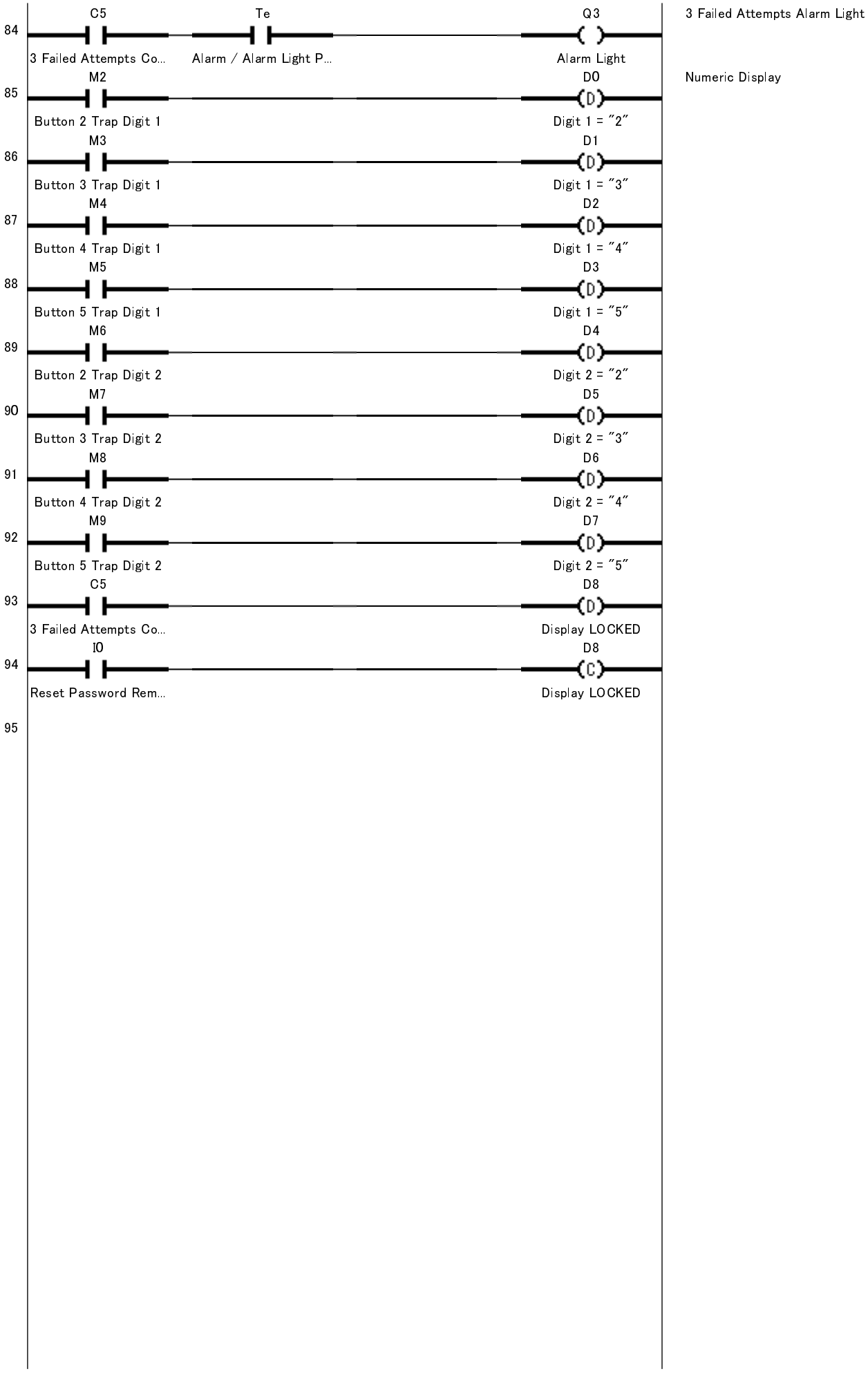
M0 work bit is reflective of any keycode button presses.

Lifting up any keycode button will cause C0 to advance once.


21
M3
Button 3 Trap Digit 1
22
M4
Button 4 Trap Digit 1
23
M5
Button 5 Trap Digit 1
24
M6
Button 2 Trap Digit 2
25
M7
Button 3 Trap Digit 2
26
M8
Button 4 Trap Digit 2
27
M9
Button 5 Trap Digit 2
28
B3
Button 3
P0
If C0 is more than 0
H0
Password Saved if lat...
H1
Saved Password Digit...
2 Rung Bank that saves Digit 1 of Password
29
B5
Button 5
30
B4
Button 4
P0
If C0 is more than 0
H0
Password Saved if lat...
H2
Saved Password Digit...
31
B5
Button 5
32
B3
Button 3
Me
Counter is at 1
H0
Password Saved if lat...
H3
Saved Password Digit...
2 Rung Bank that saves Digit 2 of Password
33
B5
Button 5
34
B4
Button 4
Me
Counter is at 1
H0
Password Saved if lat...
H4
Saved Password Digit...
35
B5
Button 5
36
P0
If C0 is more than 0
P1
If C0 is 2 or more
Me
Counter is at 1
Conditions for "Counter is at 1"
37
H0
Password Saved if lat...
P1
If C0 is 2 or more
B7
Alt Button
H0
Password Saved if lat...
Activates "Password Saved" Bit
38
H0
Password Saved if lat...
P1
If C0 is 2 or more
B7
Alt Button
C0
Entry Place Counter
PW Submission or Alt Button will reset Place Counter
39
Tf
Password Submission...
D0
Digit 1 = "2"
40
B6
Del Button
D1
Digit 1 = "3"
41
I0
Reset Password Rem...
D2
Digit 1 = "4"


42
B0
Escape Button
D3
Digit 1 = "5"
43
D4
Digit 2 = "2"
44
D5
Digit 2 = "3"
45
D6
Digit 2 = "4"
46
D7
Digit 2 = "5"
47
I0
Reset Password Rem...
H0
Password Saved if lat...
Reset Password Remote Button Clears Password from Memory
48
H0
Password Saved if lat...
B6
Del Button
H1
Saved Password Digit...
49
H2
Saved Password Digit...
50
H3
Saved Password Digit...
51
H4
Saved Password Digit...
52
C5
3 Failed Attempts Co...
53
B3
Button 3
P0
If C0 is more than 0
H0
Password Saved if lat...
C1
Password Attempt Di...
2 Rung Bank that saves Digit 1 of Password Attempt
54
B5
Button 5
55
B4
Button 4
P0
If C0 is more than 0
H0
Password Saved if lat...
C2
Password Attempt Di...
56
B5
Button 5
57
B3
Button 3
Me
Counter is at 1
H0
Password Saved if lat...
C3
Password Attempt Di...
2 Rung Bank that saves Digit 2 of Password Attempt
58
B5
Button 5
59
B4
Button 4
Me
Counter is at 1
H0
Password Saved if lat...
C4
Password Attempt Di...
60
B5
Button 5
61
H0
Password Saved if lat...
C0
Entry Place Counter
B7
Alt Button
H7
Password Entry Subm...
Submits Password Attempt
62
H1
Saved Password Digit...
C1
Password Attempt Di...
H8
Digit 1 Bit 1 Match
2 Rung Bank that verifies bit match on entry


63
H1
Saved Password Digit...
C1
Password Attempt Di...
64
H2
Saved Password Digit...
C2
Password Attempt Di...
H9
Digit 1 Bit 2 Match
2 Rung Bank that verifies bit match on entry
65
H2
Saved Password Digit...
C2
Password Attempt Di...
66
H3
Saved Password Digit...
C3
Password Attempt Di...
Ha
Digit 2 Bit 1 Match
2 Rung Bank that verifies bit match on entry
67
H3
Saved Password Digit...
C3
Password Attempt Di...
68
H4
Saved Password Digit...
C4
Password Attempt Di...
Hb
Digit 2 Bit 2 Match
2 Rung Bank that verifies bit match on entry
69
H4
Saved Password Digit...
C4
Password Attempt Di...
70
H8
Digit 1 Bit 1 Match
H9
Digit 1 Bit 2 Match
Ma
First Digit Match
First Digit Verification
71
Ha
Digit 2 Bit 1 Match
Hb
Digit 2 Bit 2 Match
Mb
Second Digit Match
Second Digit Verification
72
Ma
First Digit Match
Mb
Second Digit Match
Tf
Password Submission...
Q0
Unlock
All Bits Verified - Unlock
73
Q0
Unlock
Q1
Unlocked Light
When it is unlocked, a light activates
74
B0
Escape Button
C1
Password Attempt Di...
Reset Password Attempt
75
B6
Del Button
C2
Password Attempt Di...
76
I0
Reset Password Rem...
C3
Password Attempt Di...
77
C4
Password Attempt Di...
78
B0
Escape Button
Q0
Unlock
Relocks
79
Ma
First Digit Match
Tf
Password Submission...
Hf
Failed Attempt
If either digit in submission is wrong, fail attempt
80
Mb
Second Digit Match
Te
Alarm / Alarm Light P...
81
H7
Password Entry Subm...
Tf
Password Submission...
On-Delay For Password Submission To De-Jitter
82
Hf
Failed Attempt
C5
3 Failed Attempts Co...
3 Failed Attempts Counter
83
C5
3 Failed Attempts Co...
Te
Alarm / Alarm Light P...
Q2
Alarm
3 Failed Attempts Alarm


3 Failed Attempts Alarm Light
Numeric Display
84
C5
3 Failed Attempts Co...
Te
Alarm / Alarm Light P...
Q3
Alarm Light
85
M2
Button 2 Trap Digit 1
D0
Digit 1 = "2"
86
M3
Button 3 Trap Digit 1
D1
Digit 1 = "3"
87
M4
Button 4 Trap Digit 1
D2
Digit 1 = "4"
88
M5
Button 5 Trap Digit 1
D3
Digit 1 = "5"
89
M6
Button 2 Trap Digit 2
D4
Digit 2 = "2"
90
M7
Button 3 Trap Digit 2
D5
Digit 2 = "3"
91
M8
Button 4 Trap Digit 2
D6
Digit 2 = "4"
92
M9
Button 5 Trap Digit 2
D7
Digit 2 = "5"
93
C5
3 Failed Attempts Co...
D8
Display LOCKED
94
10
Reset Password Rem...
D8
Display LOCKED
95