

4-bit Breadboard Calculator

Oskar Fornander

2019

4-BIT BREADBOARD CALCULATOR

A

00

00

A: +1, reset

[]

[]

B

B: reset, +1

Calculate

[]

[]
[]

Calc. speed

[]

sub.
mult.

[]

Display on/off

0110

Result

000

Oskar Formander, 2019

Operations: + - x

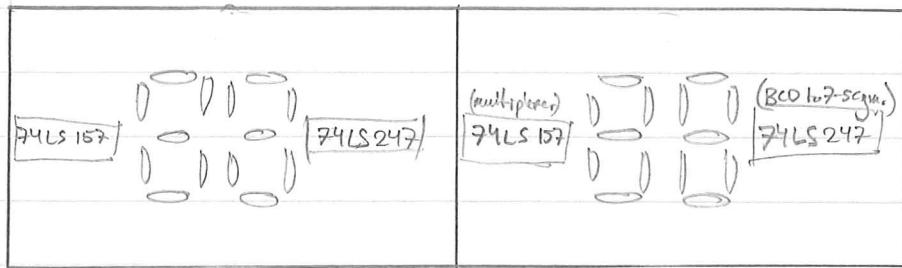
Breadboard Design

4 bit Adder/Subtractor/Multiplier

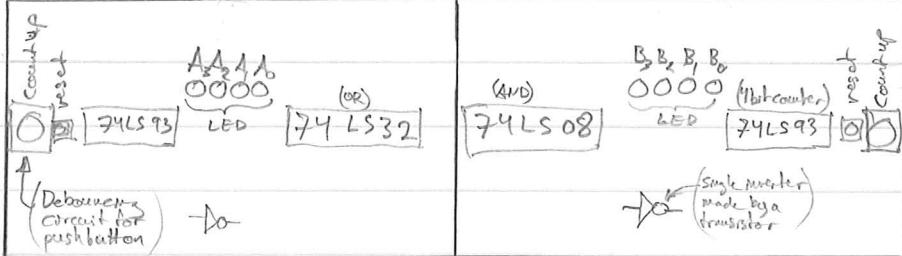
A

B

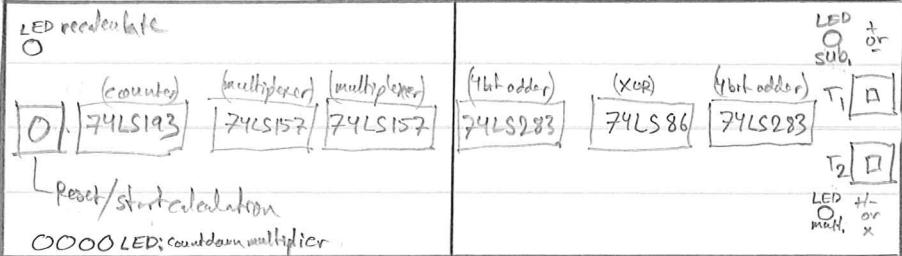
1.
Display A, B



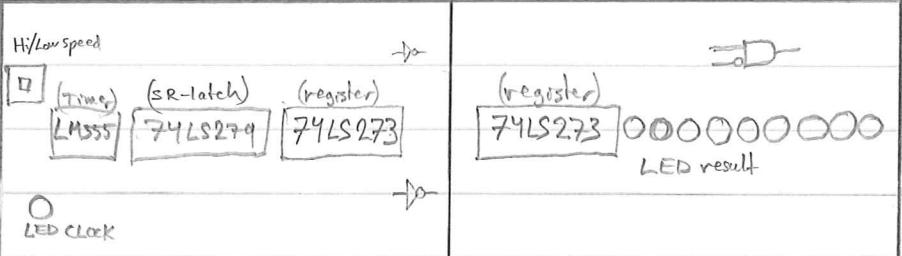
2.
Count/read A, B



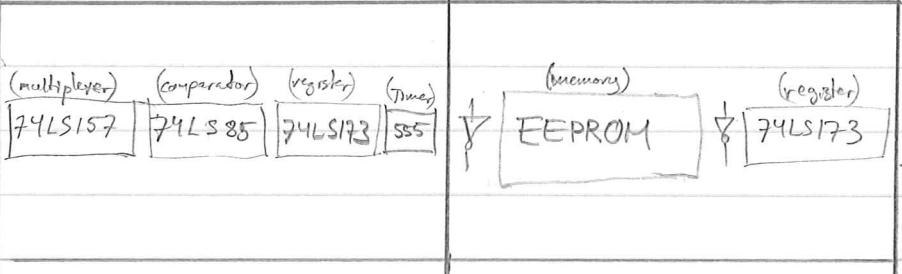
3.
counter/multiplexer,
data selector,
Adder/Subtractor



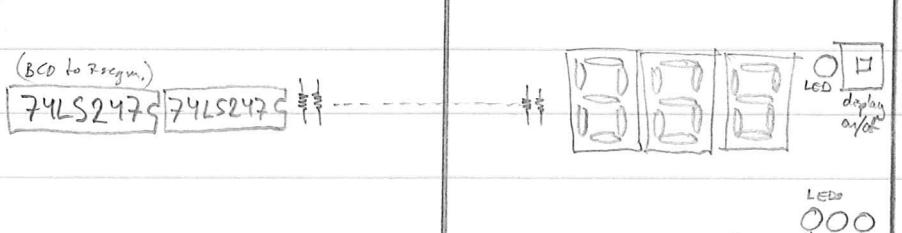
4.
clock for mult.,
register
result LED:s



5.
detecting charged signal
clock for displays
EEPROM for display
Register for 7th bits



6.
Display
Operation indication
Display on/off
LCD decoder



Operations:

A + B

A - B

A × B

$A, B \in [0, 15]$

Result $\in [-15, 225]$

List of used integrated circuits

74LS247 BCD to 7-segment decoder/driver

74LS157 Quad 2-input multiplexer

74LS93 4bit binary counter

74LS08 Quad 2-input AND gates

74LS32 Quad 2-input OR gates

74LS283 4bit binary full adder

74LS86 Quad 2-input XOR gate

74LS193 4bit up/down binary counter

74LS157 2-to-1 line multiplexer

LM555 555-timer

74LS279 Quad SR-latches

74LS273 Octal D-type flip-flop

74LS173 4bit D-type register

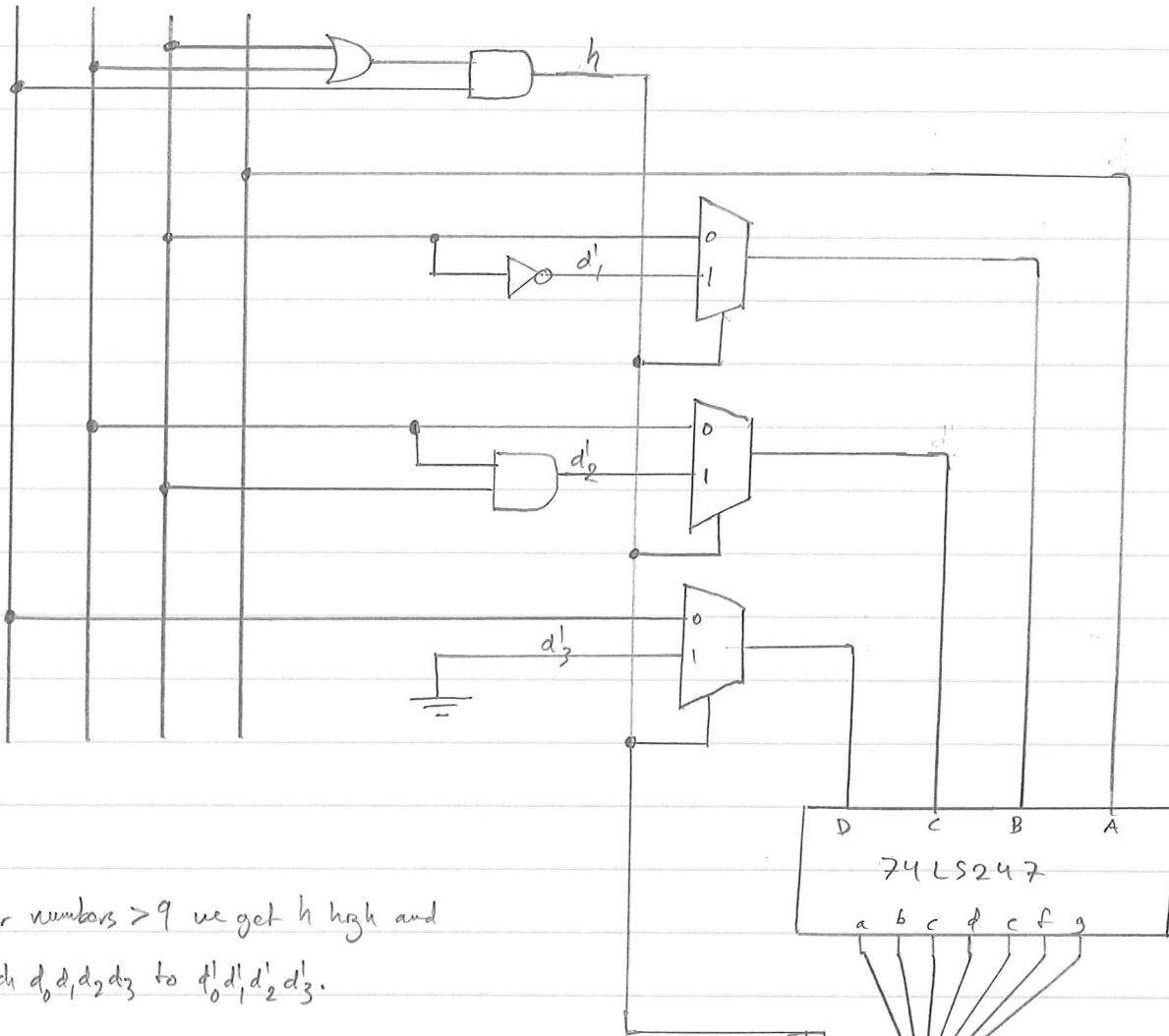
74LS85 4bit magnitude comparator

AT28C64B 64K EEPROM (8Kx8)

Circuit Diagram: Display A and B. 4 bit binary number to 7 segment display

IA, IB

$d_3 \ d_2 \ d_1 \ d_0$



For numbers ≥ 9 we get h high and switch d_0, d_1, d_2, d_3 to d'_0, d'_1, d'_2, d'_3 .

1010 maps to 0000

1011 \rightarrow 0001

$$d'_0 = d_0$$

1100 \rightarrow 0010

$$d'_1 = \bar{d}_1$$

1101 \rightarrow 0011

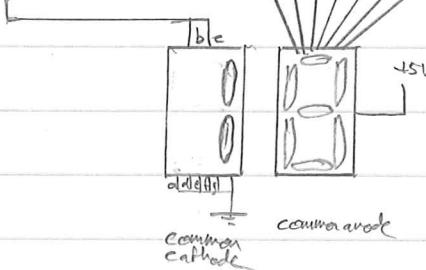
$$d'_2 = d_1 \cdot d_2$$

1110 \rightarrow 0100

$$d'_3 = 0$$

1111 \rightarrow 0101

$$h = d_3 \cdot (d_2 + d_1)$$

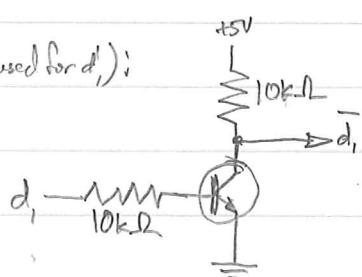


Karnaugh map for h (1 for numbers ≥ 9)

d_3, d_2	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	0	0	1	1

$$f(d_3, d_2, d_1, d_0) = d_2 \cdot d_3 + d_1 \cdot d_3 = d_3 \cdot (d_2 + d_1)$$

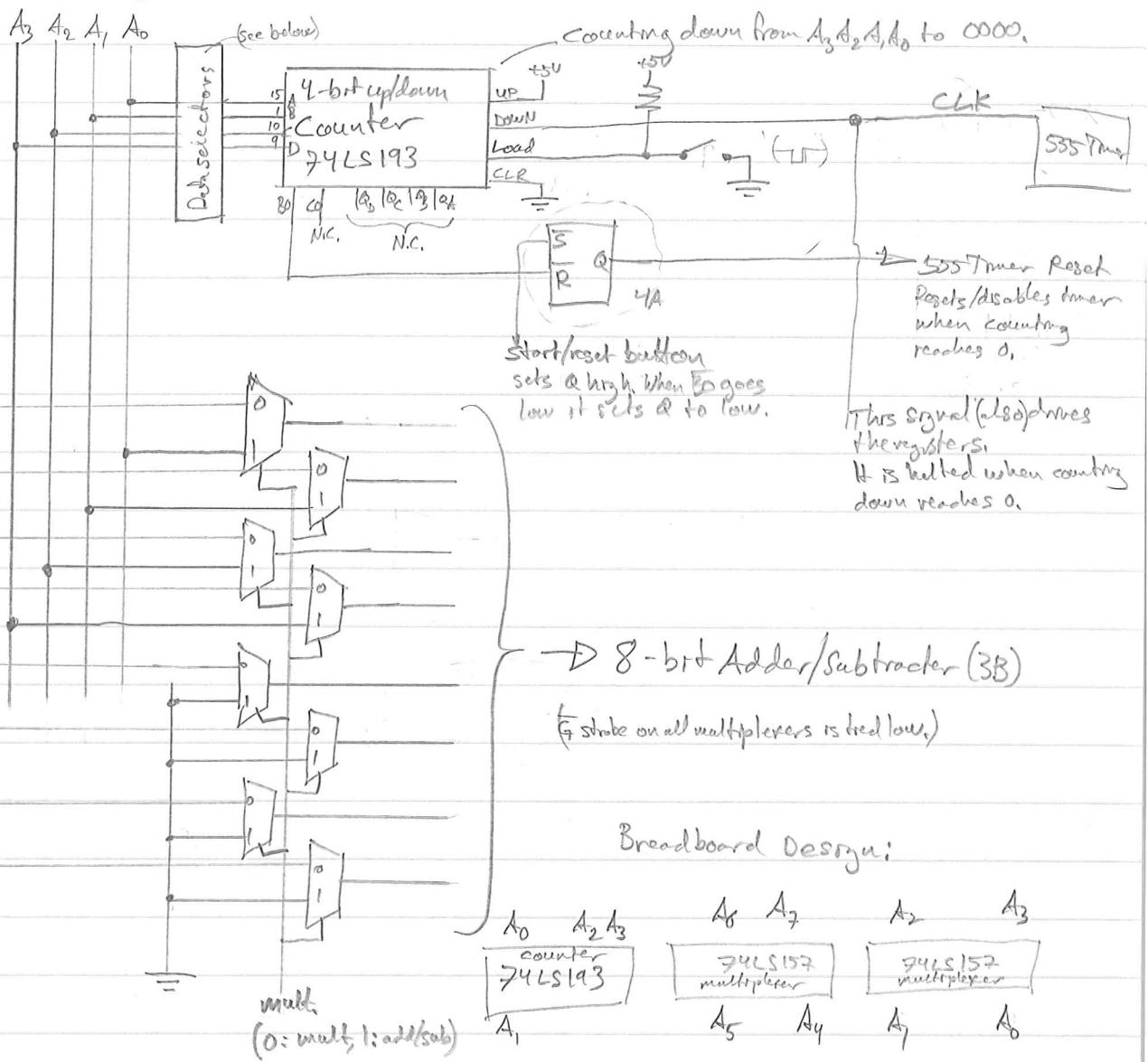
Inverter (used for d'_i):



$$\begin{cases} V_{IL} = 0,8V \text{ (max)} \\ V_{IH} = 2,0V \text{ (min)} \end{cases}$$

Circuit Diagram: multiplication counter and multiplexer

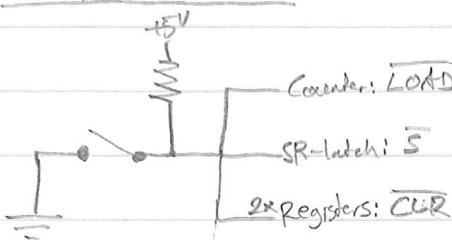
3A



3A

Reset/start button

Resets counter and registers and starts the clock to begin the calculation



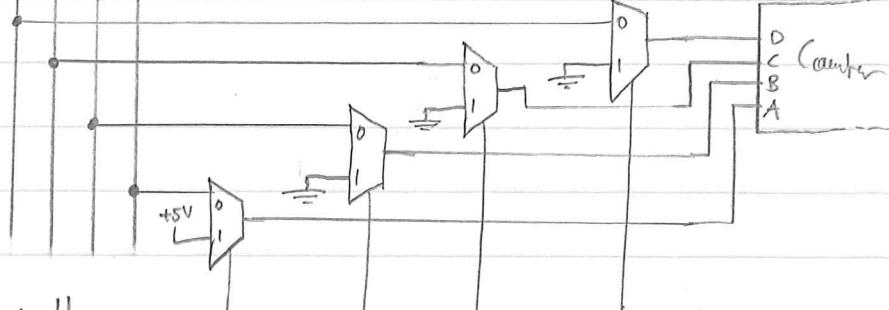
- preload the multiplicand in the counter

- enable the clock to run

- reset the outputs of the registers

Data selectors into multiplication counter (see above):

$A_3 A_2 A_1 A_0$



5A

mult preset value to counter

0 (mult) $A_3 A_2 A_1 A_0$

1 (add/sub) $0001 \rightarrow$

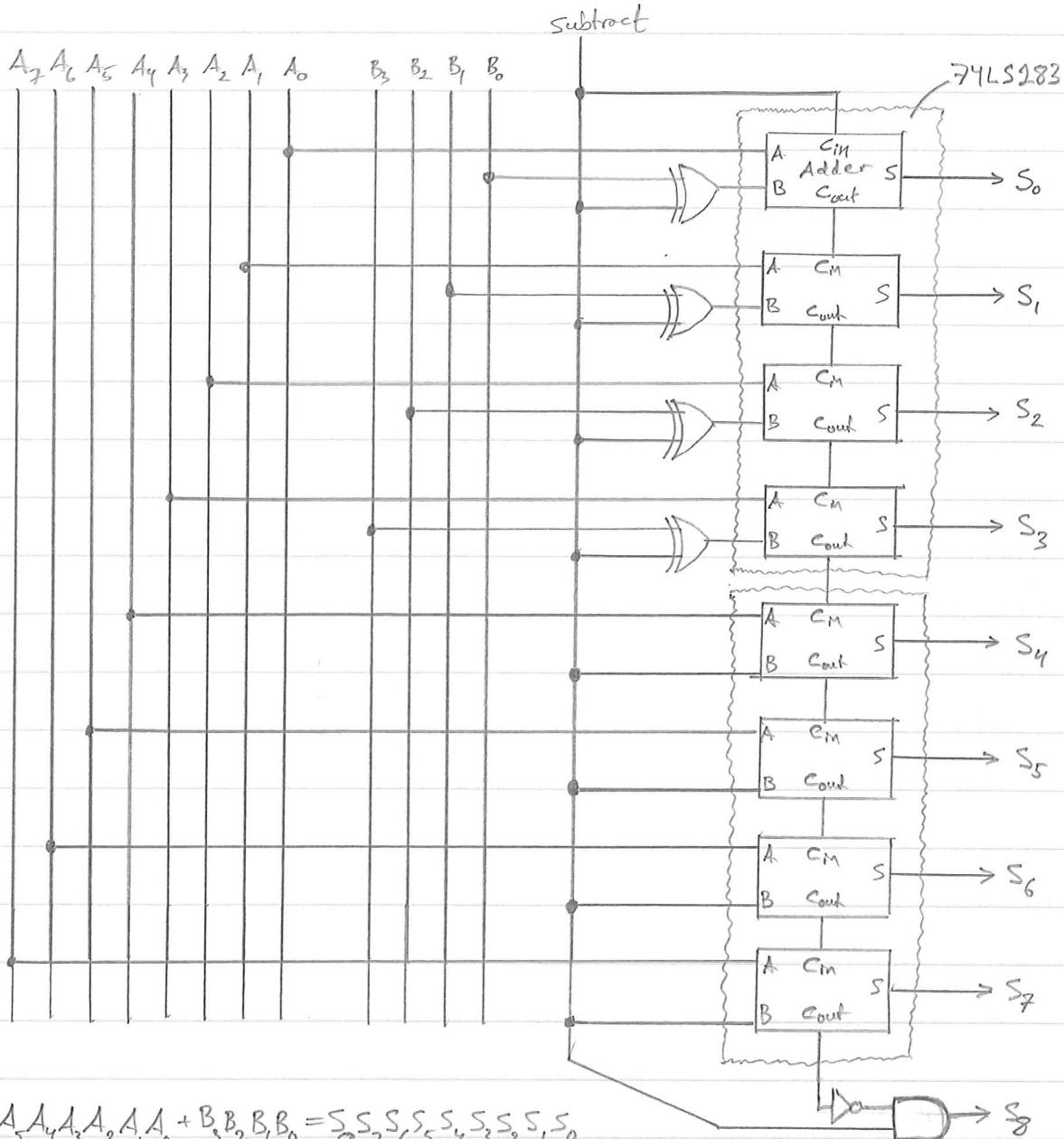
This gives one clock pulse

for addition/subtraction, which makes the clock stop after add/sub is done, and it makes addition/subtraction for $A=0$ work.

mult

Circuit Diagram: 8-bit Adder (used repeatedly for multiplication)

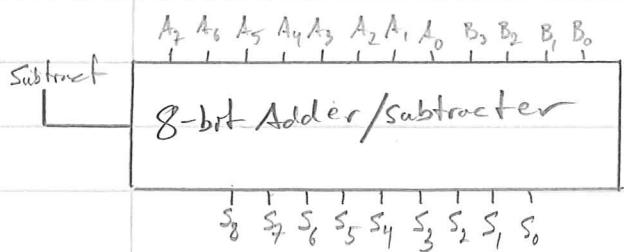
3B



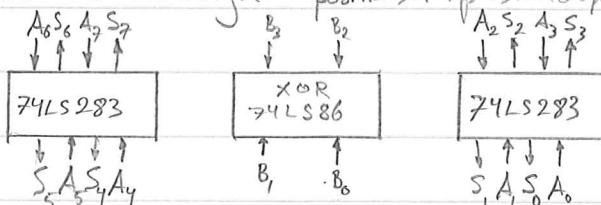
$$A_7 A_6 A_5 A_4 A_3 A_2 A_1 A_0 + B_7 B_6 B_5 B_4 B_3 B_2 B_1 B_0 = S_8 S_7 S_6 S_5 S_4 S_3 S_2 S_1 S_0$$

If the subtract signal is high, the adder basically works

as a subtracter, by inverting B (inverting each bit and feed a one into the first carry). If the sum (difference) is negative it will be represented in two's complement form,

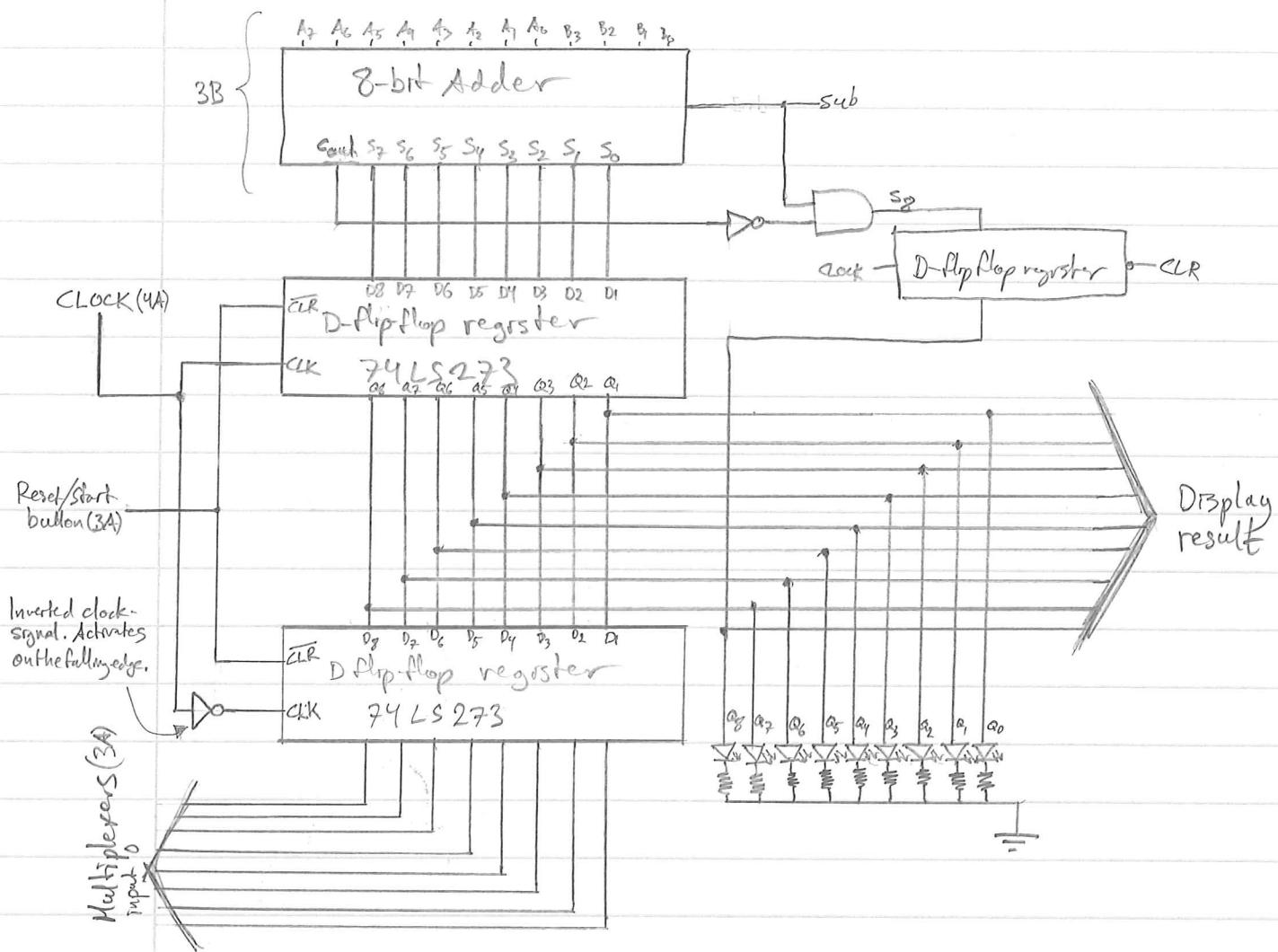


Breadboard design — positions of inputs and outputs:

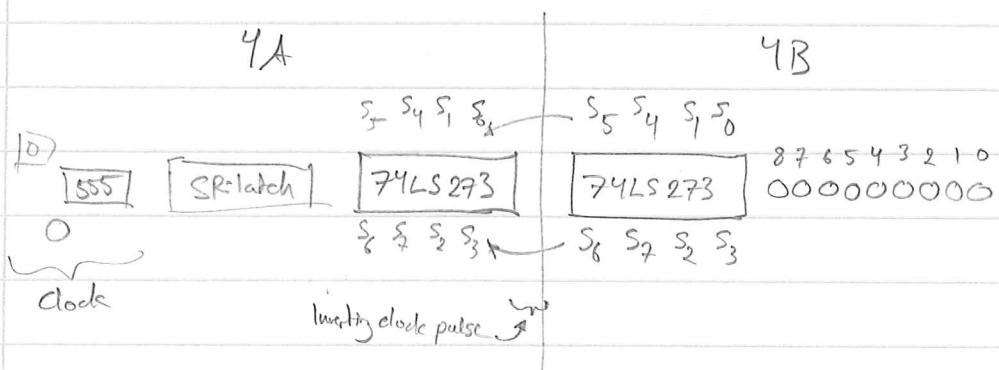


Circuit Diagram: Registers for multiplication

4A, 4B



Breadboard design: (red wires)



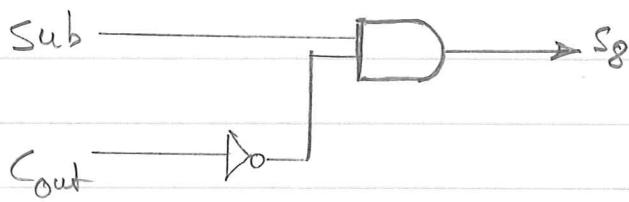
Circuit Diagram: The 9th bit (S_8)

4B

The ninth bit is not simply the last carry in the addition. It must be a 0 when the result is positive and a 1 when it is negative. It can be calculated as follows:

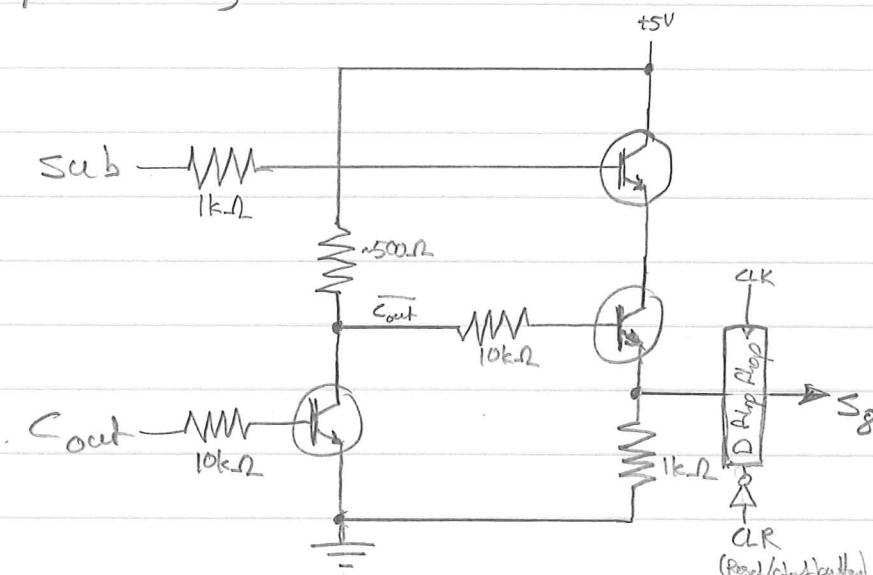
$$S_8 = \text{Sub} \times \overline{C_{\text{out}}}$$

(or $S_8 = \text{Sub} \oplus C_{\text{out}}$, since the case for $\text{Sub}=0, C_{\text{out}}=1$ does not matter, because C_{out} cannot be 1 for addition ($\text{Sub}=0$) with only 4-bit numbers to add. The other formula, however, is easier to implement.)



Sub	C_{out}	S_8
addition	0	0
	1	X
subtraction	1	1
	1	0

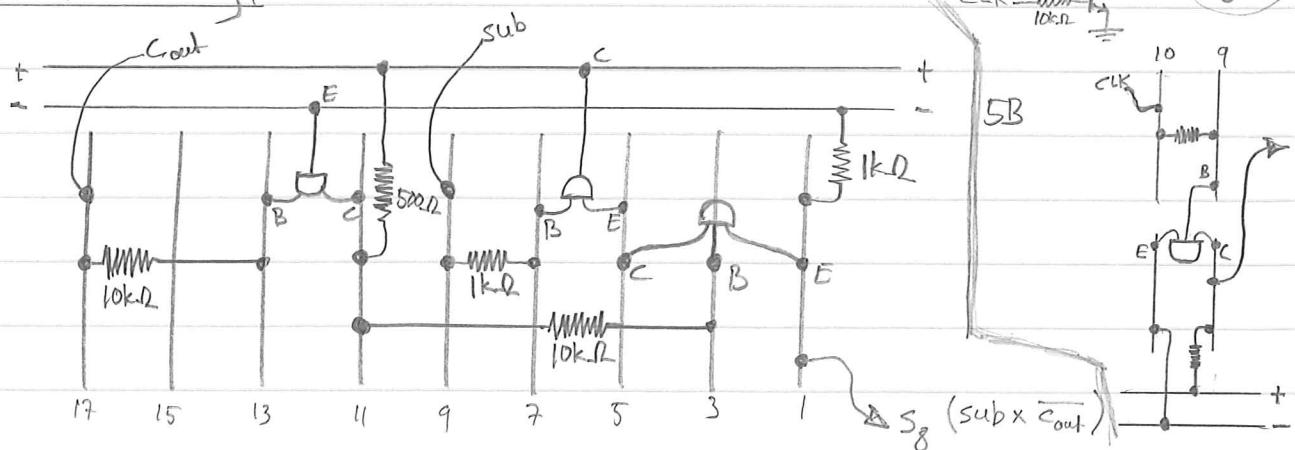
For space restrictions on the breadboard this circuit is implemented using transistors and resistors.



By feeding the S_8 signal into a Dtype register (5B) we can make it show simultaneously with the other bits.

Breadboard design

4B



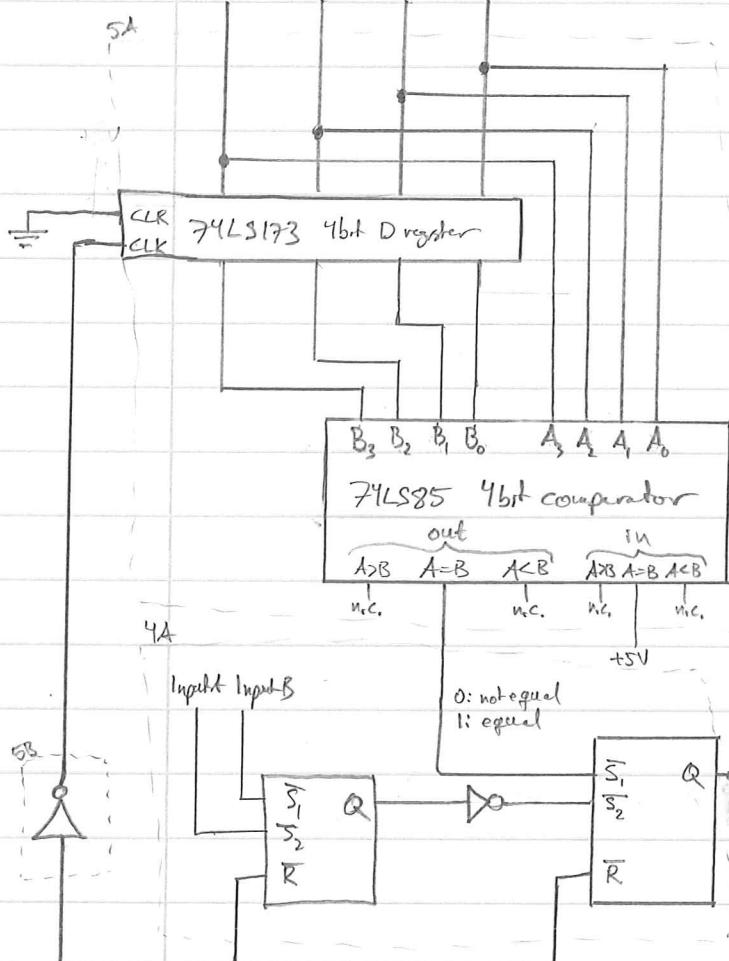
Detecting a changed signal to indicate need for recalculation

A change in one of these signals will cause the shown result to be inaccurate and therefore must be recalculated: Inputs A and B, reset and B, sub, mult.

The standard values of these signals are:

Input A	Input B	Resch A	Resch B	sub	mult	
1	1	0	0	0	0	(mult)
1	1	0	0	0	1	(add)
1	1	0	0	1	1	(sub)

ResetA ResetB sub mult

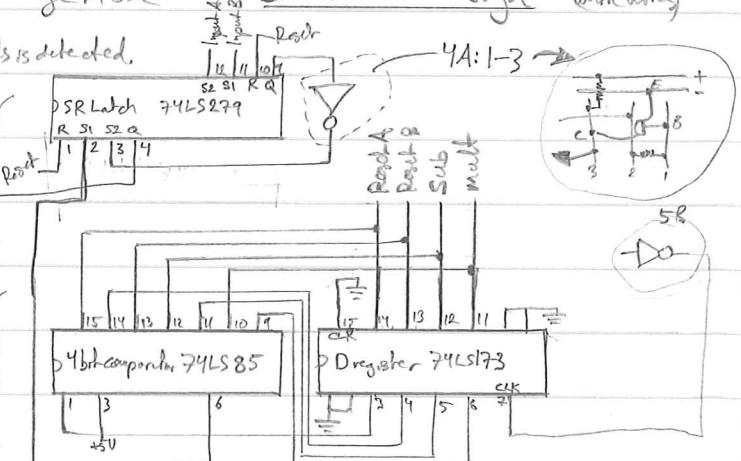


Q is high when a change in one or more of the signals is detected.

S	R	Q
1	1	Q ₀
0	1	1
1	0	0
0	0	?

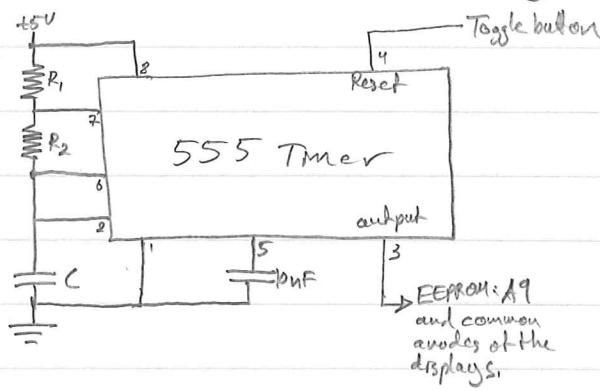
$$\overline{S} = \overline{S}_1 \times \overline{S}_2 \quad \left(\begin{array}{l} \text{\overline{S} is high iff \overline{s}_1 and \overline{s}_2 are high.} \\ \text{\overline{S} is low if one or both of \overline{s}_1 and \overline{s}_2 are low.} \end{array} \right)$$

Breadboard design (white wire)



Displaying Result with EEPROM

Clock circuit to multiplex the 7 segments displays:



A 555 timer in astable mode.

Desired frequency at least 100Hz, and a ratio of high to low times close to 1.

$$C: 2\mu F$$

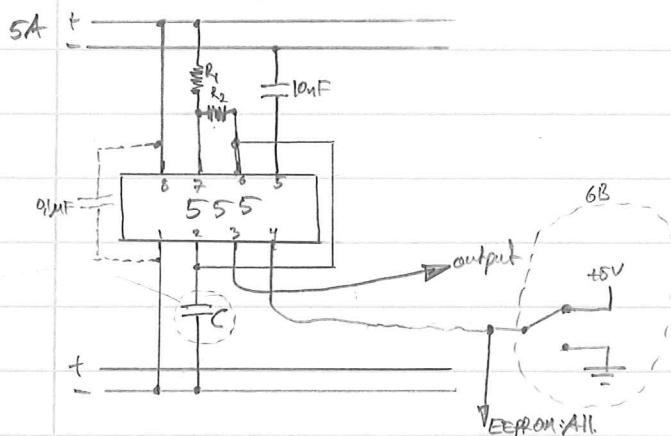
$$R_1: 10k\Omega$$

$$R_2: 1M\Omega$$

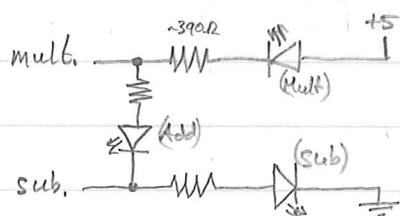
$$f: 358Hz$$

$$\text{ratio: } 1,01$$

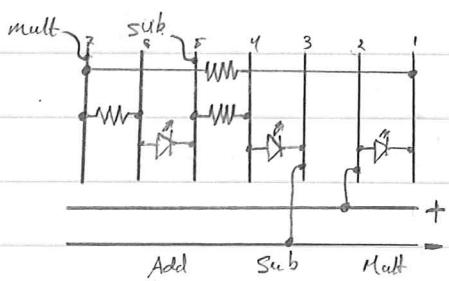
Breadboard design of the clock circuit:



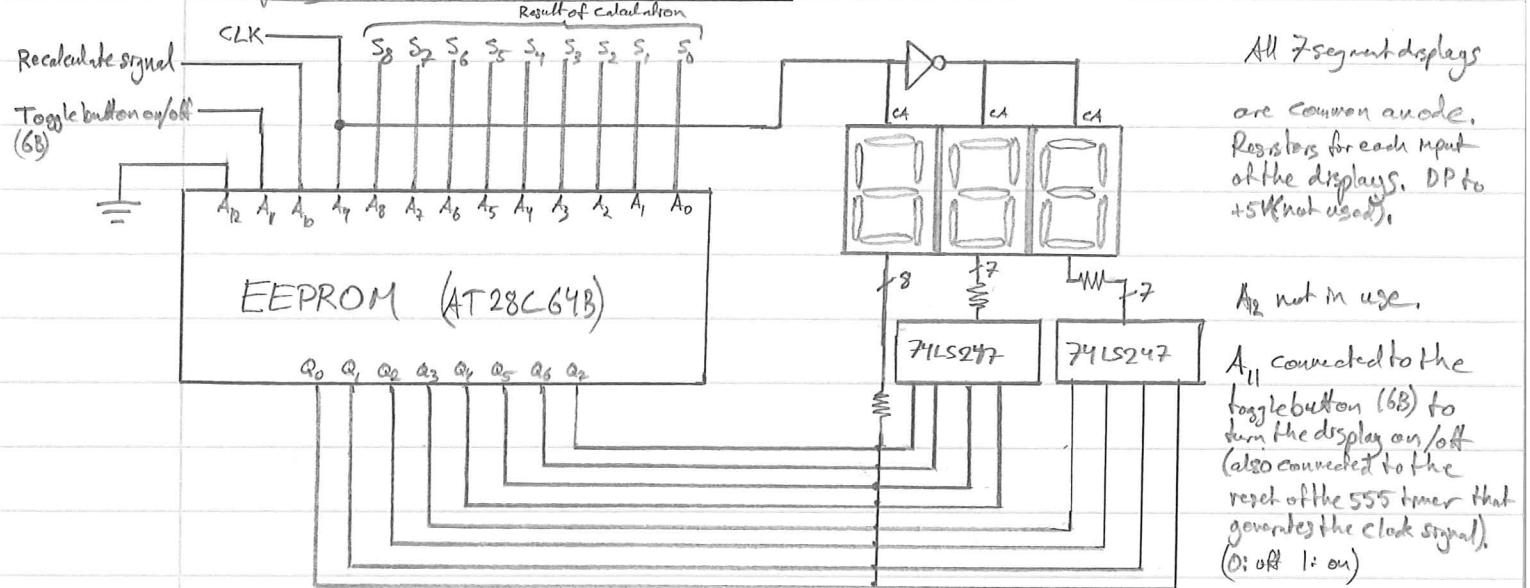
Indicate the type of operation with LEDs:



	sub	mult	Add	Sub	Mult
subtraction:	1	1	0	1	0
addition:	0	1	1	0	0
multiplication:	0	0	0	0	1



Displaying results with EEPROM



All 7 segment displays are common anode. Registers for each input of the displays, DP to +5V (not used).

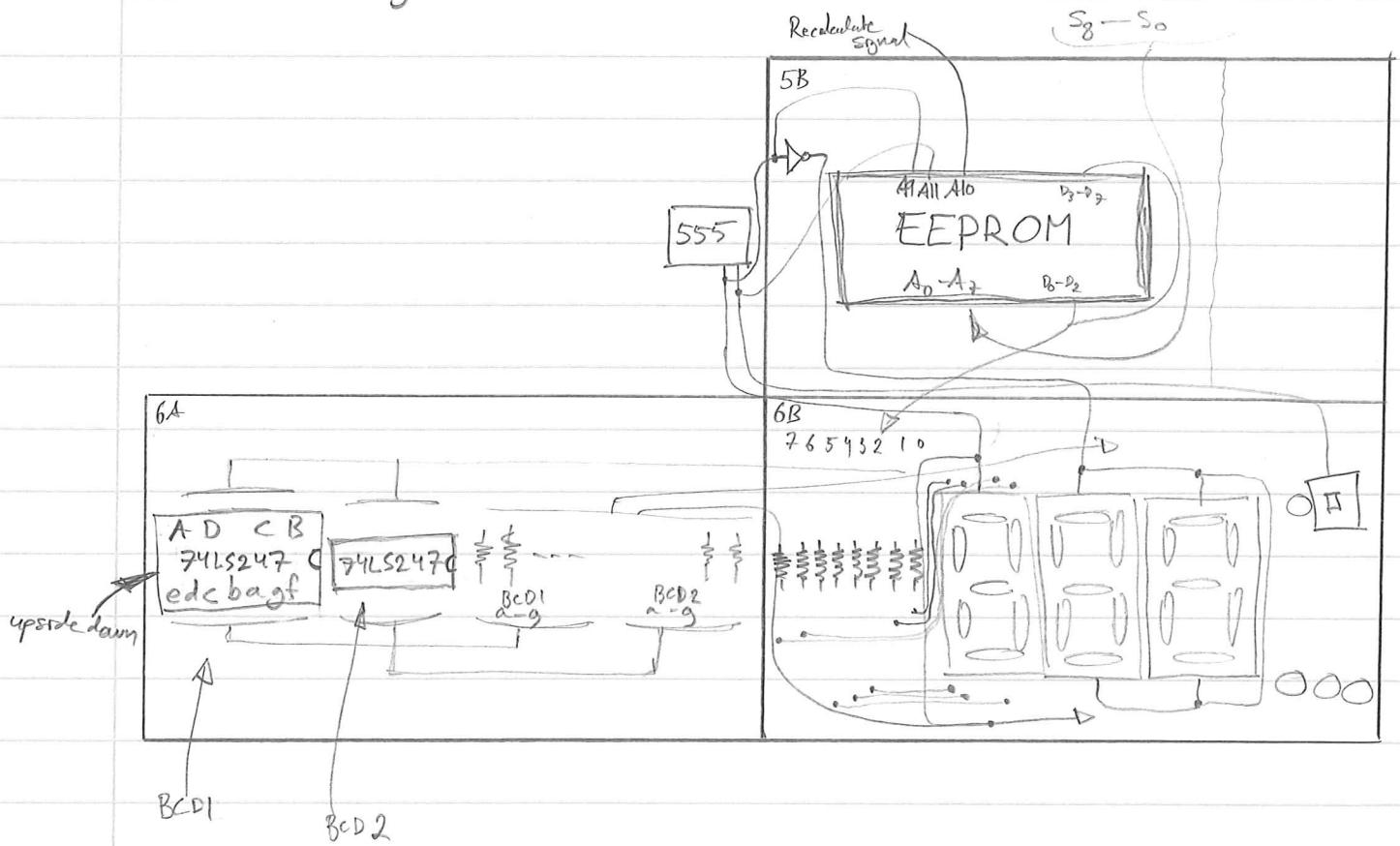
A_{11} not in use.

A_{11} connected to the togglebutton (6B) to turn the display on/off (also connected to the reset of the 555 timer that generates the clock signal). (0: off, 1: on)

A_{10} connected to the recalculate signal to clear the display when a calculation has to be performed. (0: on, 1: off)

A_9 is the clock input for multiplexing (0: BCD₁, and BCD₂, 1: third digit).

Breadboard design



A	D ₀	A	D ₁
B	D ₁	B	D ₂
C	D ₂	C	D ₃
D	D ₃	D	D ₇

Content of the EEPROM

A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0	← Address of the EEPROM
													Number to display
													Digit to show (0: BCD, and BCD ₂ , 1: 7 segment 3rd digit)
													Clear all (0: number displayed 1: nothing displayed (all bytes off)) (Recalculate signal)
													Turn display on/off (1: number displayed 0: nothing displayed (and clock halted)) (Toggle button)
													Not in use (ground)

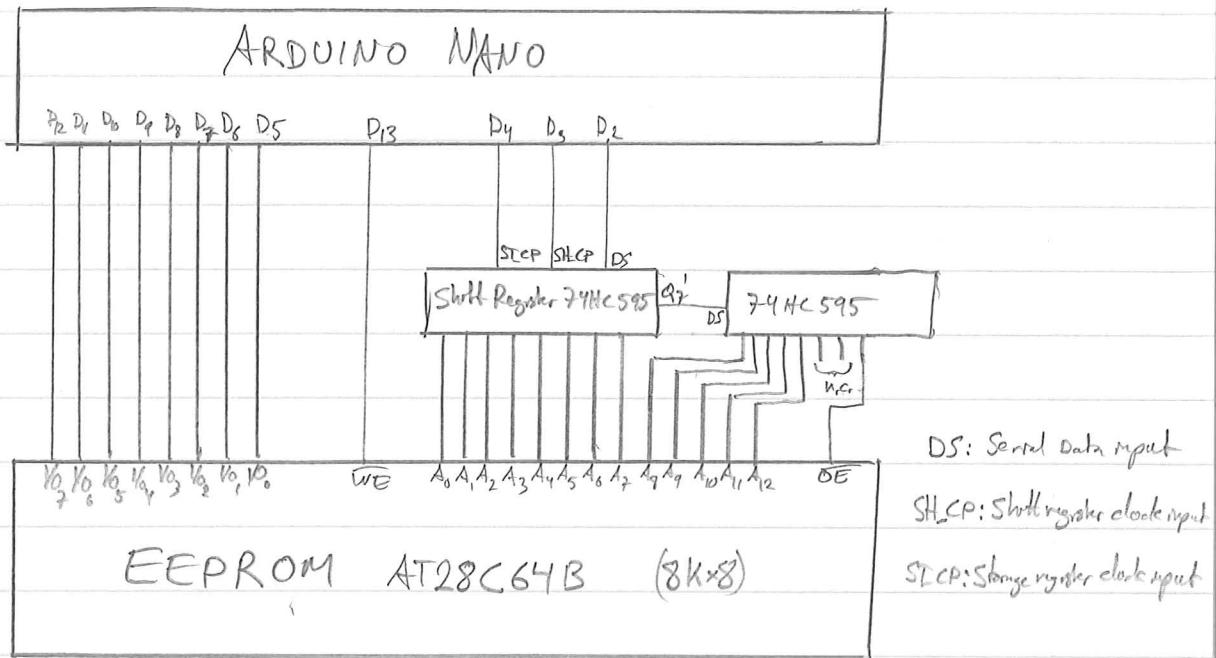
$A_{12} A_{11} A_{10} A_9 A_8 A_0$	$D_7 D_6 D_5 D_4 D_3 D_2 D_1 D_0$	← Output of the EEPROM
0 0 0 X	BCD ₂	BCD ₁
0 0 1 X	7 segment decoded digit/sign	
0 1 1 X X	1 1 1 1 1 1 1 1	FF shows blank displays
0 0 X X X	1 1 1 1 1 1 1 1	

} Encoded for common anode displays

EEPROM is programmed for all numbers in the desired range : $[-15, 225]$

EEPROM Programmer

I use an Arduino Nano to program the EEPROM (8Kx8).



The values are shifted MSB first, two bytes:

0X X 0 0 0 0 0 | 0 0 0 0 0 0 0, 0, 0,
OE Address

Built as Ben Eater's EEPROM programmer for his 8-bit breadboard computer project.]

Addition, Subtraction, Multiplication in binary

A and B are 4-bit binary numbers 0000 to 1111 (0 to 15).

$$A, B \in [0, 15]$$

$$A+B \in [0, 30]$$

$$A-B \in [-15, 15]$$

$$A \times B \in [0, 225]$$

Addition is straight forward with the adder circuit.

Subtraction adds $-B$ to A ($A-B = A+(-B)$)

by negating B (we get two's complement negative number by inverting every single bit and adding one (in the carry-in of the first adder), therefore the sub-sign is high for subtraction and low for addition).

The result is given as a positive or negative binary number & two's complement.

Multiplication uses repeated addition (preferred over shifting and adding because it gets the multiples of the multiplicand (B) during the process, which can be shown with a slow clock pulse).

$$A \times B = \underbrace{B + B + \dots + B}_{A \text{ terms}}$$

Only positive numbers are used in multiplication.

Allowing for negative numbers we need 9 bits to cover the desired range $[-15, 255]$.

9 bits gives us

$$\text{min: } 100\ 000\ 000 \quad (-256)$$

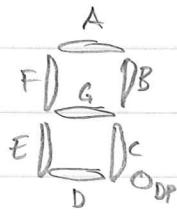
$$\text{max: } 011\ 111\ 111 \quad (255)$$

So, we have a range of $[-256, 255]$.

The adder is an 8-bit adder, which will be enough, with the last carry as the 9th bit in the final result.

number	positive	negative
0	0 0000 0000	0 0000 0000
1	0 0000 0001	1 1111 1111
2	0 0000 0010	1 1111 1110
3	0 0000 0011	1 1111 1101
4	0 0000 0100	1 1111 1100
5	0 0000 0101	1 1111 1011
6	0 0000 0110	1 1111 1010
7	0 0000 0111	1 1111 1001
8	0 0000 1000	1 1111 1000
9	0 0000 1001	1 1111 0111
10	0 0000 1010	1 1111 0110
11	0 0000 1011	1 1111 0101
12	0 0000 1100	1 1111 0100
13	0 0000 1101	1 1111 0011
14	0 0000 1110	1 1111 0010
15	0 0000 1111	1 1111 0001

7 segments Display - encoded digits



The numbers 0-9 (or 0-F for hexadecimal), and maybe some extra signs) can be stored as one byte to drive a 7 segment display (CC or inverted for CA). Let A be the most significant bit and DP the least significant bit.

(CC and CA values are inversely complementary to FF.)

Number	Binary	A	B	C	D	E	F	G	DP	Hexadecimal value	Hexadecimal value
0	0000	1	1	1	1	1	1	0	0	FC	03
1	0001	0	1	1	0	0	0	0	0	60	9F
2	0010	1	1	0	1	1	0	1	0	DA	25
3	0011	1	1	1	1	0	0	1	0	F2	0D
4	0100	0	1	1	0	0	1	1	0	66	99
5	0101	1	0	1	1	0	1	1	0	B6	49
6	0110	1	0	1	1	1	1	1	0	BE	41
7	0111	1	1	1	0	0	0	0	0	E0	1F
8	1000	1	1	1	1	1	1	1	0	FE	01
9	1001	1	1	1	0	0	1	1	0	E6	19
A	1010	1	1	1	0	1	1	1	0	EE	11
B	1011	0	0	1	1	1	1	1	0	3E	C1
C	1100	1	0	0	1	1	1	0	0	9C	63
D	1101	0	1	1	1	1	0	1	0	7A	85
E	1110	1	0	0	1	1	1	1	0	9E	61
F	1111	1	0	0	0	1	1	1	0	8E	71

0 1 2 3 4 5 6 7 8 9 A B C D E F

Show the values encoded for the numbers to display.

Digits 1 and 2 are BCD, and digit 3 are 7 segment encoded

Number (hex) d3 d2 d1 clear all (d3 d2 d1)

000	(000):	ff	f	0	ff	f	f
001	(001):	ff	f	1	ff	f	f
002	(002):	ff	f	2	ff	f	f
003	(003):	ff	f	3	ff	f	f
004	(004):	ff	f	4	ff	f	f
005	(005):	ff	f	5	ff	f	f
006	(006):	ff	f	6	ff	f	f
007	(007):	ff	f	7	ff	f	f
008	(008):	ff	f	8	ff	f	f
009	(009):	ff	f	9	ff	f	f
010	(00a):	ff	1	0	ff	f	f
011	(00b):	ff	1	1	ff	f	f
012	(00c):	ff	1	2	ff	f	f
013	(00d):	ff	1	3	ff	f	f
014	(00e):	ff	1	4	ff	f	f
015	(00f):	ff	1	5	ff	f	f
016	(010):	ff	1	6	ff	f	f
017	(011):	ff	1	7	ff	f	f
018	(012):	ff	1	8	ff	f	f
019	(013):	ff	1	9	ff	f	f
020	(014):	ff	2	0	ff	f	f
021	(015):	ff	2	1	ff	f	f
022	(016):	ff	2	2	ff	f	f
023	(017):	ff	2	3	ff	f	f
024	(018):	ff	2	4	ff	f	f
025	(019):	ff	2	5	ff	f	f
026	(01a):	ff	2	6	ff	f	f
027	(01b):	ff	2	7	ff	f	f
028	(01c):	ff	2	8	ff	f	f
029	(01d):	ff	2	9	ff	f	f
030	(01e):	ff	3	0	ff	f	f
031	(01f):	ff	3	1	ff	f	f
032	(020):	ff	3	2	ff	f	f
033	(021):	ff	3	3	ff	f	f
034	(022):	ff	3	4	ff	f	f
035	(023):	ff	3	5	ff	f	f
036	(024):	ff	3	6	ff	f	f
037	(025):	ff	3	7	ff	f	f
038	(026):	ff	3	8	ff	f	f
039	(027):	ff	3	9	ff	f	f
040	(028):	ff	4	0	ff	f	f
041	(029):	ff	4	1	ff	f	f
042	(02a):	ff	4	2	ff	f	f
043	(02b):	ff	4	3	ff	f	f
044	(02c):	ff	4	4	ff	f	f
045	(02d):	ff	4	5	ff	f	f
046	(02e):	ff	4	6	ff	f	f
047	(02f):	ff	4	7	ff	f	f
048	(030):	ff	4	8	ff	f	f
049	(031):	ff	4	9	ff	f	f
050	(032):	ff	5	0	ff	f	f

051	(033):	ff	5	1	ff	f	f
052	(034):	ff	5	2	ff	f	f
053	(035):	ff	5	3	ff	f	f
054	(036):	ff	5	4	ff	f	f
055	(037):	ff	5	5	ff	f	f
056	(038):	ff	5	6	ff	f	f
057	(039):	ff	5	7	ff	f	f
058	(03a):	ff	5	8	ff	f	f
059	(03b):	ff	5	9	ff	f	f
060	(03c):	ff	6	0	ff	f	f
061	(03d):	ff	6	1	ff	f	f
062	(03e):	ff	6	2	ff	f	f
063	(03f):	ff	6	3	ff	f	f
064	(040):	ff	6	4	ff	f	f
065	(041):	ff	6	5	ff	f	f
066	(042):	ff	6	6	ff	f	f
067	(043):	ff	6	7	ff	f	f
068	(044):	ff	6	8	ff	f	f
069	(045):	ff	6	9	ff	f	f
070	(046):	ff	7	0	ff	f	f
071	(047):	ff	7	1	ff	f	f
072	(048):	ff	7	2	ff	f	f
073	(049):	ff	7	3	ff	f	f
074	(04a):	ff	7	4	ff	f	f
075	(04b):	ff	7	5	ff	f	f
076	(04c):	ff	7	6	ff	f	f
077	(04d):	ff	7	7	ff	f	f
078	(04e):	ff	7	8	ff	f	f
079	(04f):	ff	7	9	ff	f	f
080	(050):	ff	8	0	ff	f	f
081	(051):	ff	8	1	ff	f	f
082	(052):	ff	8	2	ff	f	f
083	(053):	ff	8	3	ff	f	f
084	(054):	ff	8	4	ff	f	f
085	(055):	ff	8	5	ff	f	f
086	(056):	ff	8	6	ff	f	f
087	(057):	ff	8	7	ff	f	f
088	(058):	ff	8	8	ff	f	f
089	(059):	ff	8	9	ff	f	f
090	(05a):	ff	9	0	ff	f	f
091	(05b):	ff	9	1	ff	f	f
092	(05c):	ff	9	2	ff	f	f
093	(05d):	ff	9	3	ff	f	f
094	(05e):	ff	9	4	ff	f	f
095	(05f):	ff	9	5	ff	f	f
096	(060):	ff	9	6	ff	f	f
097	(061):	ff	9	7	ff	f	f
098	(062):	ff	9	8	ff	f	f
099	(063):	ff	9	9	ff	f	f
100	(064):	9f	0	0	ff	f	f
101	(065):	9f	0	1	ff	f	f
102	(066):	9f	0	2	ff	f	f
103	(067):	9f	0	3	ff	f	f
104	(068):	9f	0	4	ff	f	f

105	(069):	9f	0	5	ff	f	f
106	(06a):	9f	0	6	ff	f	f
107	(06b):	9f	0	7	ff	f	f
108	(06c):	9f	0	8	ff	f	f
109	(06d):	9f	0	9	ff	f	f
110	(06e):	9f	1	0	ff	f	f
111	(06f):	9f	1	1	ff	f	f
112	(070):	9f	1	2	ff	f	f
113	(071):	9f	1	3	ff	f	f
114	(072):	9f	1	4	ff	f	f
115	(073):	9f	1	5	ff	f	f
116	(074):	9f	1	6	ff	f	f
117	(075):	9f	1	7	ff	f	f
118	(076):	9f	1	8	ff	f	f
119	(077):	9f	1	9	ff	f	f
120	(078):	9f	2	0	ff	f	f
121	(079):	9f	2	1	ff	f	f
122	(07a):	9f	2	2	ff	f	f
123	(07b):	9f	2	3	ff	f	f
124	(07c):	9f	2	4	ff	f	f
125	(07d):	9f	2	5	ff	f	f
126	(07e):	9f	2	6	ff	f	f
127	(07f):	9f	2	7	ff	f	f
128	(080):	9f	2	8	ff	f	f
129	(081):	9f	2	9	ff	f	f
130	(082):	9f	3	0	ff	f	f
131	(083):	9f	3	1	ff	f	f
132	(084):	9f	3	2	ff	f	f
133	(085):	9f	3	3	ff	f	f
134	(086):	9f	3	4	ff	f	f
135	(087):	9f	3	5	ff	f	f
136	(088):	9f	3	6	ff	f	f
137	(089):	9f	3	7	ff	f	f
138	(08a):	9f	3	8	ff	f	f
139	(08b):	9f	3	9	ff	f	f
140	(08c):	9f	4	0	ff	f	f
141	(08d):	9f	4	1	ff	f	f
142	(08e):	9f	4	2	ff	f	f
143	(08f):	9f	4	3	ff	f	f
144	(090):	9f	4	4	ff	f	f
145	(091):	9f	4	5	ff	f	f
146	(092):	9f	4	6	ff	f	f
147	(093):	9f	4	7	ff	f	f
148	(094):	9f	4	8	ff	f	f
149	(095):	9f	4	9	ff	f	f
150	(096):	9f	5	0	ff	f	f
151	(097):	9f	5	1	ff	f	f
152	(098):	9f	5	2	ff	f	f
153	(099):	9f	5	3	ff	f	f
154	(09a):	9f	5	4	ff	f	f
155	(09b):	9f	5	5	ff	f	f
156	(09c):	9f	5	6	ff	f	f
157	(09d):	9f	5	7	ff	f	f
158	(09e):	9f	5	8	ff	f	f

159	(09f):	9f	5	9	ff	f	f
160	(0a0):	9f	6	0	ff	f	f
161	(0a1):	9f	6	1	ff	f	f
162	(0a2):	9f	6	2	ff	f	f
163	(0a3):	9f	6	3	ff	f	f
164	(0a4):	9f	6	4	ff	f	f
165	(0a5):	9f	6	5	ff	f	f
166	(0a6):	9f	6	6	ff	f	f
167	(0a7):	9f	6	7	ff	f	f
168	(0a8):	9f	6	8	ff	f	f
169	(0a9):	9f	6	9	ff	f	f
170	(0aa):	9f	7	0	ff	f	f
171	(0ab):	9f	7	1	ff	f	f
172	(0ac):	9f	7	2	ff	f	f
173	(0ad):	9f	7	3	ff	f	f
174	(0ae):	9f	7	4	ff	f	f
175	(0af):	9f	7	5	ff	f	f
176	(0b0):	9f	7	6	ff	f	f
177	(0b1):	9f	7	7	ff	f	f
178	(0b2):	9f	7	8	ff	f	f
179	(0b3):	9f	7	9	ff	f	f
180	(0b4):	9f	8	0	ff	f	f
181	(0b5):	9f	8	1	ff	f	f
182	(0b6):	9f	8	2	ff	f	f
183	(0b7):	9f	8	3	ff	f	f
184	(0b8):	9f	8	4	ff	f	f
185	(0b9):	9f	8	5	ff	f	f
186	(0ba):	9f	8	6	ff	f	f
187	(0bb):	9f	8	7	ff	f	f
188	(0bc):	9f	8	8	ff	f	f
189	(0bd):	9f	8	9	ff	f	f
190	(0be):	9f	9	0	ff	f	f
191	(0bf):	9f	9	1	ff	f	f
192	(0c0):	9f	9	2	ff	f	f
193	(0c1):	9f	9	3	ff	f	f
194	(0c2):	9f	9	4	ff	f	f
195	(0c3):	9f	9	5	ff	f	f
196	(0c4):	9f	9	6	ff	f	f
197	(0c5):	9f	9	7	ff	f	f
198	(0c6):	9f	9	8	ff	f	f
199	(0c7):	9f	9	9	ff	f	f
200	(0c8):	25	0	0	ff	f	f
201	(0c9):	25	0	1	ff	f	f
202	(0ca):	25	0	2	ff	f	f
203	(0cb):	25	0	3	ff	f	f
204	(0cc):	25	0	4	ff	f	f
205	(0cd):	25	0	5	ff	f	f
206	(0ce):	25	0	6	ff	f	f
207	(0cf):	25	0	7	ff	f	f
208	(0d0):	25	0	8	ff	f	f
209	(0d1):	25	0	9	ff	f	f
210	(0d2):	25	1	0	ff	f	f
211	(0d3):	25	1	1	ff	f	f
212	(0d4):	25	1	2	ff	f	f

213	(0d5):	25	1	3	ff	f	f
214	(0d6):	25	1	4	ff	f	f
215	(0d7):	25	1	5	ff	f	f
216	(0d8):	25	1	6	ff	f	f
217	(0d9):	25	1	7	ff	f	f
218	(0da):	25	1	8	ff	f	f
219	(0db):	25	1	9	ff	f	f
220	(0dc):	25	2	0	ff	f	f
221	(0dd):	25	2	1	ff	f	f
222	(0de):	25	2	2	ff	f	f
223	(0df):	25	2	3	ff	f	f
224	(0e0):	25	2	4	ff	f	f
225	(0e1):	25	2	5	ff	f	f
226	(0e2):	25	2	6	ff	f	f
227	(0e3):	25	2	7	ff	f	f
228	(0e4):	25	2	8	ff	f	f
229	(0e5):	25	2	9	ff	f	f
230	(0e6):	25	3	0	ff	f	f
231	(0e7):	25	3	1	ff	f	f
232	(0e8):	25	3	2	ff	f	f
233	(0e9):	25	3	3	ff	f	f
234	(0ea):	25	3	4	ff	f	f
235	(0eb):	25	3	5	ff	f	f
236	(0ec):	25	3	6	ff	f	f
237	(0ed):	25	3	7	ff	f	f
238	(0ee):	25	3	8	ff	f	f
239	(0ef):	25	3	9	ff	f	f
240	(0f0):	25	4	0	ff	f	f
241	(0f1):	25	4	1	ff	f	f
242	(0f2):	25	4	2	ff	f	f
243	(0f3):	25	4	3	ff	f	f
244	(0f4):	25	4	4	ff	f	f
245	(0f5):	25	4	5	ff	f	f
246	(0f6):	25	4	6	ff	f	f
247	(0f7):	25	4	7	ff	f	f
248	(0f8):	25	4	8	ff	f	f
249	(0f9):	25	4	9	ff	f	f
250	(0fa):	25	5	0	ff	f	f
251	(0fb):	25	5	1	ff	f	f
252	(0fc):	25	5	2	ff	f	f
253	(0fd):	25	5	3	ff	f	f
254	(0fe):	25	5	4	ff	f	f
255	(0ff):	25	5	5	ff	f	f
-256	(100):	25	5	6	ff	f	f
-255	(101):	25	5	5	ff	f	f
-254	(102):	25	5	4	ff	f	f
-253	(103):	25	5	3	ff	f	f
-252	(104):	25	5	2	ff	f	f
-251	(105):	25	5	1	ff	f	f
-250	(106):	25	5	0	ff	f	f
-249	(107):	25	4	9	ff	f	f
-248	(108):	25	4	8	ff	f	f
-247	(109):	25	4	7	ff	f	f
-246	(10a):	25	4	6	ff	f	f

225 is the highest possible result
for the calculator.

For three digit negative numbers
the third display will show the
digit instead of the minus sign.
(-256 to -100) No problem in
this project since the lowest
negative result that can be shown
will be -15.

-245	(10b):	25	4	5	ff	f	f
-244	(10c):	25	4	4	ff	f	f
-243	(10d):	25	4	3	ff	f	f
-242	(10e):	25	4	2	ff	f	f
-241	(10f):	25	4	1	ff	f	f
-240	(110):	25	4	0	ff	f	f
-239	(111):	25	3	9	ff	f	f
-238	(112):	25	3	8	ff	f	f
-237	(113):	25	3	7	ff	f	f
-236	(114):	25	3	6	ff	f	f
-235	(115):	25	3	5	ff	f	f
-234	(116):	25	3	4	ff	f	f
-233	(117):	25	3	3	ff	f	f
-232	(118):	25	3	2	ff	f	f
-231	(119):	25	3	1	ff	f	f
-230	(11a):	25	3	0	ff	f	f
-229	(11b):	25	2	9	ff	f	f
-228	(11c):	25	2	8	ff	f	f
-227	(11d):	25	2	7	ff	f	f
-226	(11e):	25	2	6	ff	f	f
-225	(11f):	25	2	5	ff	f	f
-224	(120):	25	2	4	ff	f	f
-223	(121):	25	2	3	ff	f	f
-222	(122):	25	2	2	ff	f	f
-221	(123):	25	2	1	ff	f	f
-220	(124):	25	2	0	ff	f	f
-219	(125):	25	1	9	ff	f	f
-218	(126):	25	1	8	ff	f	f
-217	(127):	25	1	7	ff	f	f
-216	(128):	25	1	6	ff	f	f
-215	(129):	25	1	5	ff	f	f
-214	(12a):	25	1	4	ff	f	f
-213	(12b):	25	1	3	ff	f	f
-212	(12c):	25	1	2	ff	f	f
-211	(12d):	25	1	1	ff	f	f
-210	(12e):	25	1	0	ff	f	f
-209	(12f):	25	0	9	ff	f	f
-208	(130):	25	0	8	ff	f	f
-207	(131):	25	0	7	ff	f	f
-206	(132):	25	0	6	ff	f	f
-205	(133):	25	0	5	ff	f	f
-204	(134):	25	0	4	ff	f	f
-203	(135):	25	0	3	ff	f	f
-202	(136):	25	0	2	ff	f	f
-201	(137):	25	0	1	ff	f	f
-200	(138):	25	0	0	ff	f	f
-199	(139):	9f	9	9	ff	f	f
-198	(13a):	9f	9	8	ff	f	f
-197	(13b):	9f	9	7	ff	f	f
-196	(13c):	9f	9	6	ff	f	f
-195	(13d):	9f	9	5	ff	f	f
-194	(13e):	9f	9	4	ff	f	f
-193	(13f):	9f	9	3	ff	f	f
-192	(140):	9f	9	2	ff	f	f

-191	(141):	9f	9	1	ff	f	f
-190	(142):	9f	9	0	ff	f	f
-189	(143):	9f	8	9	ff	f	f
-188	(144):	9f	8	8	ff	f	f
-187	(145):	9f	8	7	ff	f	f
-186	(146):	9f	8	6	ff	f	f
-185	(147):	9f	8	5	ff	f	f
-184	(148):	9f	8	4	ff	f	f
-183	(149):	9f	8	3	ff	f	f
-182	(14a):	9f	8	2	ff	f	f
-181	(14b):	9f	8	1	ff	f	f
-180	(14c):	9f	8	0	ff	f	f
-179	(14d):	9f	7	9	ff	f	f
-178	(14e):	9f	7	8	ff	f	f
-177	(14f):	9f	7	7	ff	f	f
-176	(150):	9f	7	6	ff	f	f
-175	(151):	9f	7	5	ff	f	f
-174	(152):	9f	7	4	ff	f	f
-173	(153):	9f	7	3	ff	f	f
-172	(154):	9f	7	2	ff	f	f
-171	(155):	9f	7	1	ff	f	f
-170	(156):	9f	7	0	ff	f	f
-169	(157):	9f	6	9	ff	f	f
-168	(158):	9f	6	8	ff	f	f
-167	(159):	9f	6	7	ff	f	f
-166	(15a):	9f	6	6	ff	f	f
-165	(15b):	9f	6	5	ff	f	f
-164	(15c):	9f	6	4	ff	f	f
-163	(15d):	9f	6	3	ff	f	f
-162	(15e):	9f	6	2	ff	f	f
-161	(15f):	9f	6	1	ff	f	f
-160	(160):	9f	6	0	ff	f	f
-159	(161):	9f	5	9	ff	f	f
-158	(162):	9f	5	8	ff	f	f
-157	(163):	9f	5	7	ff	f	f
-156	(164):	9f	5	6	ff	f	f
-155	(165):	9f	5	5	ff	f	f
-154	(166):	9f	5	4	ff	f	f
-153	(167):	9f	5	3	ff	f	f
-152	(168):	9f	5	2	ff	f	f
-151	(169):	9f	5	1	ff	f	f
-150	(16a):	9f	5	0	ff	f	f
-149	(16b):	9f	4	9	ff	f	f
-148	(16c):	9f	4	8	ff	f	f
-147	(16d):	9f	4	7	ff	f	f
-146	(16e):	9f	4	6	ff	f	f
-145	(16f):	9f	4	5	ff	f	f
-144	(170):	9f	4	4	ff	f	f
-143	(171):	9f	4	3	ff	f	f
-142	(172):	9f	4	2	ff	f	f
-141	(173):	9f	4	1	ff	f	f
-140	(174):	9f	4	0	ff	f	f
-139	(175):	9f	3	9	ff	f	f
-138	(176):	9f	3	8	ff	f	f

-137	(177):	9f	3	7	ff	f	f
-136	(178):	9f	3	6	ff	f	f
-135	(179):	9f	3	5	ff	f	f
-134	(17a):	9f	3	4	ff	f	f
-133	(17b):	9f	3	3	ff	f	f
-132	(17c):	9f	3	2	ff	f	f
-131	(17d):	9f	3	1	ff	f	f
-130	(17e):	9f	3	0	ff	f	f
-129	(17f):	9f	2	9	ff	f	f
-128	(180):	9f	2	8	ff	f	f
-127	(181):	9f	2	7	ff	f	f
-126	(182):	9f	2	6	ff	f	f
-125	(183):	9f	2	5	ff	f	f
-124	(184):	9f	2	4	ff	f	f
-123	(185):	9f	2	3	ff	f	f
-122	(186):	9f	2	2	ff	f	f
-121	(187):	9f	2	1	ff	f	f
-120	(188):	9f	2	0	ff	f	f
-119	(189):	9f	1	9	ff	f	f
-118	(18a):	9f	1	8	ff	f	f
-117	(18b):	9f	1	7	ff	f	f
-116	(18c):	9f	1	6	ff	f	f
-115	(18d):	9f	1	5	ff	f	f
-114	(18e):	9f	1	4	ff	f	f
-113	(18f):	9f	1	3	ff	f	f
-112	(190):	9f	1	2	ff	f	f
-111	(191):	9f	1	1	ff	f	f
-110	(192):	9f	1	0	ff	f	f
-109	(193):	9f	0	9	ff	f	f
-108	(194):	9f	0	8	ff	f	f
-107	(195):	9f	0	7	ff	f	f
-106	(196):	9f	0	6	ff	f	f
-105	(197):	9f	0	5	ff	f	f
-104	(198):	9f	0	4	ff	f	f
-103	(199):	9f	0	3	ff	f	f
-102	(19a):	9f	0	2	ff	f	f
-101	(19b):	9f	0	1	ff	f	f
-100	(19c):	9f	0	0	ff	f	f
-099	(19d):	fd	9	9	ff	f	f
-098	(19e):	fd	9	8	ff	f	f
-097	(19f):	fd	9	7	ff	f	f
-096	(1a0):	fd	9	6	ff	f	f
-095	(1a1):	fd	9	5	ff	f	f
-094	(1a2):	fd	9	4	ff	f	f
-093	(1a3):	fd	9	3	ff	f	f
-092	(1a4):	fd	9	2	ff	f	f
-091	(1a5):	fd	9	1	ff	f	f
-090	(1a6):	fd	9	0	ff	f	f
-089	(1a7):	fd	8	9	ff	f	f
-088	(1a8):	fd	8	8	ff	f	f
-087	(1a9):	fd	8	7	ff	f	f
-086	(1aa):	fd	8	6	ff	f	f
-085	(1ab):	fd	8	5	ff	f	f
-084	(1ac):	fd	8	4	ff	f	f

-083	(1ad):	fd	8	3	ff	f	f
-082	(1ae):	fd	8	2	ff	f	f
-081	(1af):	fd	8	1	ff	f	f
-080	(1b0):	fd	8	0	ff	f	f
-079	(1b1):	fd	7	9	ff	f	f
-078	(1b2):	fd	7	8	ff	f	f
-077	(1b3):	fd	7	7	ff	f	f
-076	(1b4):	fd	7	6	ff	f	f
-075	(1b5):	fd	7	5	ff	f	f
-074	(1b6):	fd	7	4	ff	f	f
-073	(1b7):	fd	7	3	ff	f	f
-072	(1b8):	fd	7	2	ff	f	f
-071	(1b9):	fd	7	1	ff	f	f
-070	(1ba):	fd	7	0	ff	f	f
-069	(1bb):	fd	6	9	ff	f	f
-068	(1bc):	fd	6	8	ff	f	f
-067	(1bd):	fd	6	7	ff	f	f
-066	(1be):	fd	6	6	ff	f	f
-065	(1bf):	fd	6	5	ff	f	f
-064	(1c0):	fd	6	4	ff	f	f
-063	(1c1):	fd	6	3	ff	f	f
-062	(1c2):	fd	6	2	ff	f	f
-061	(1c3):	fd	6	1	ff	f	f
-060	(1c4):	fd	6	0	ff	f	f
-059	(1c5):	fd	5	9	ff	f	f
-058	(1c6):	fd	5	8	ff	f	f
-057	(1c7):	fd	5	7	ff	f	f
-056	(1c8):	fd	5	6	ff	f	f
-055	(1c9):	fd	5	5	ff	f	f
-054	(1ca):	fd	5	4	ff	f	f
-053	(1cb):	fd	5	3	ff	f	f
-052	(1cc):	fd	5	2	ff	f	f
-051	(1cd):	fd	5	1	ff	f	f
-050	(1ce):	fd	5	0	ff	f	f
-049	(1cf):	fd	4	9	ff	f	f
-048	(1d0):	fd	4	8	ff	f	f
-047	(1d1):	fd	4	7	ff	f	f
-046	(1d2):	fd	4	6	ff	f	f
-045	(1d3):	fd	4	5	ff	f	f
-044	(1d4):	fd	4	4	ff	f	f
-043	(1d5):	fd	4	3	ff	f	f
-042	(1d6):	fd	4	2	ff	f	f
-041	(1d7):	fd	4	1	ff	f	f
-040	(1d8):	fd	4	0	ff	f	f
-039	(1d9):	fd	3	9	ff	f	f
-038	(1da):	fd	3	8	ff	f	f
-037	(1db):	fd	3	7	ff	f	f
-036	(1dc):	fd	3	6	ff	f	f
-035	(1dd):	fd	3	5	ff	f	f
-034	(1de):	fd	3	4	ff	f	f
-033	(1df):	fd	3	3	ff	f	f
-032	(1e0):	fd	3	2	ff	f	f
-031	(1e1):	fd	3	1	ff	f	f
-030	(1e2):	fd	3	0	ff	f	f

-029	(1e3):	fd	2	9	ff	f	f
-028	(1e4):	fd	2	8	ff	f	f
-027	(1e5):	fd	2	7	ff	f	f
-026	(1e6):	fd	2	6	ff	f	f
-025	(1e7):	fd	2	5	ff	f	f
-024	(1e8):	fd	2	4	ff	f	f
-023	(1e9):	fd	2	3	ff	f	f
-022	(1ea):	fd	2	2	ff	f	f
-021	(1eb):	fd	2	1	ff	f	f
-020	(1ec):	fd	2	0	ff	f	f
-019	(1ed):	fd	1	9	ff	f	f
-018	(1ee):	fd	1	8	ff	f	f
-017	(1ef):	fd	1	7	ff	f	f
-016	(1f0):	fd	1	6	ff	f	f
-015	(1f1):	fd	1	5	ff	f	f
-014	(1f2):	fd	1	4	ff	f	f
-013	(1f3):	fd	1	3	ff	f	f
-012	(1f4):	fd	1	2	ff	f	f
-011	(1f5):	fd	1	1	ff	f	f
-010	(1f6):	fd	1	0	ff	f	f
-009	(1f7):	fd	f	9	ff	f	f
-008	(1f8):	fd	f	8	ff	f	f
-007	(1f9):	fd	f	7	ff	f	f
-006	(1fa):	fd	f	6	ff	f	f
-005	(1fb):	fd	f	5	ff	f	f
-004	(1fc):	fd	f	4	ff	f	f
-003	(1fd):	fd	f	3	ff	f	f
-002	(1fe):	fd	f	2	ff	f	f
-001	(1ff):	fd	f	1	ff	f	f

— Negative results for the calculator will only range between -1 and -15.