Programming a Calculator

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The HP 20b

- Originally 2 line display
- User is able to toggle RPN on and off
- Calculator is often repurposed and reprogrammed due to open software.
- uses Atmel AT91SAM7L128 30 MHz processor

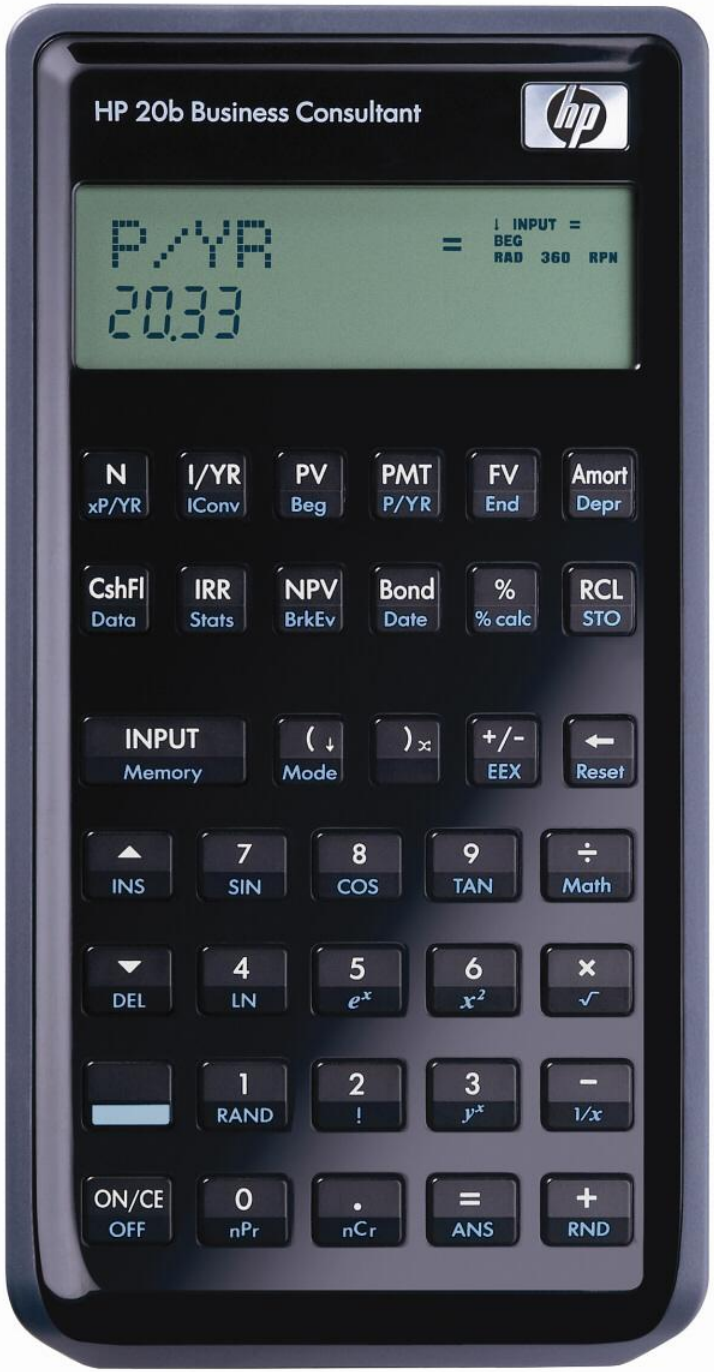
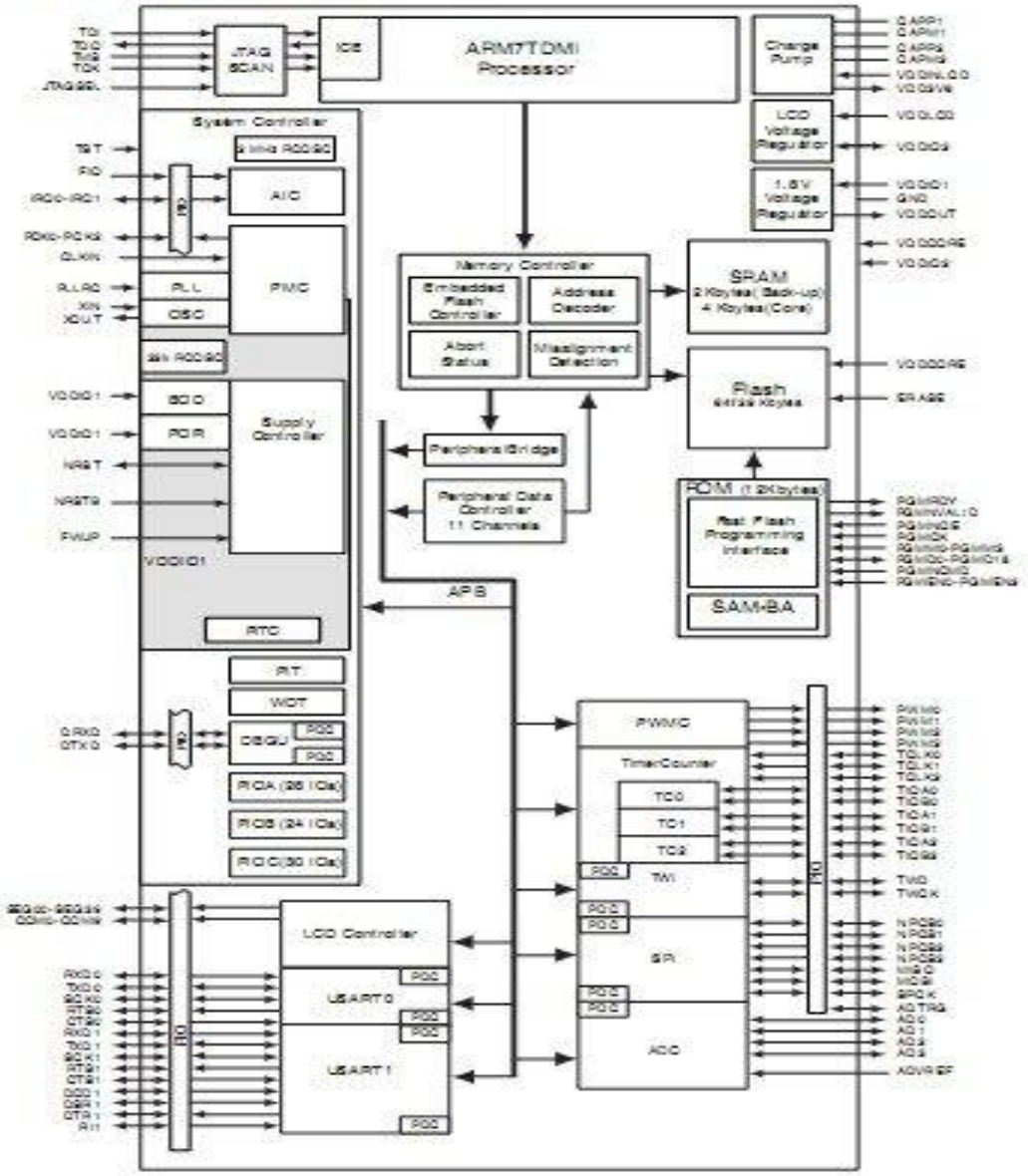


Figure 2-1. AT91SAM7L128/64 Block Diagram



Reverse Polish Notation

- First commercially available in 1963
- Parenthesis and brackets are unnecessary
- Instead has operations follow the numbers they are operating on

Features of RPN

- Makes use of a stack to store operands
- Each operator only works on two numbers
- Automatic storage of results allows for more complicated operations
- Operations cause calculations to occur immediately

image of kdfp from: http://www.chezfred.org.uk

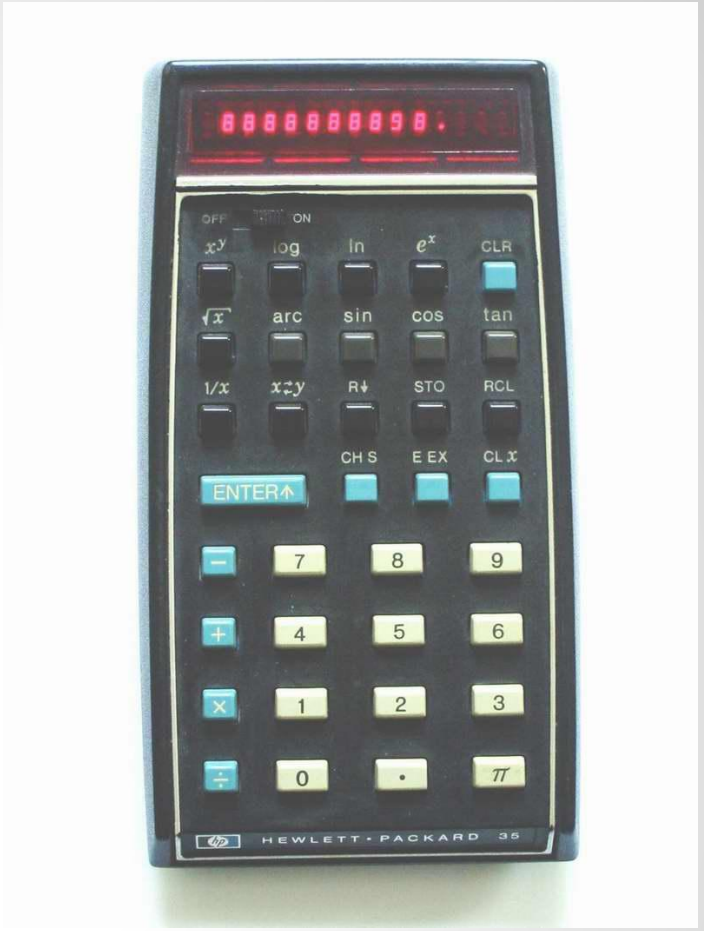


image of hp 35 from: http://www.thimet.de/calccollection/calculators/HP-35/Contents.htm

Example

(1+2)*3+4 is 1,2+3*4+ . Evaluate to 13.

1+2*(3+4) turns to 1,2,3,4+*+ . Evaluate to 15

More on the stacks

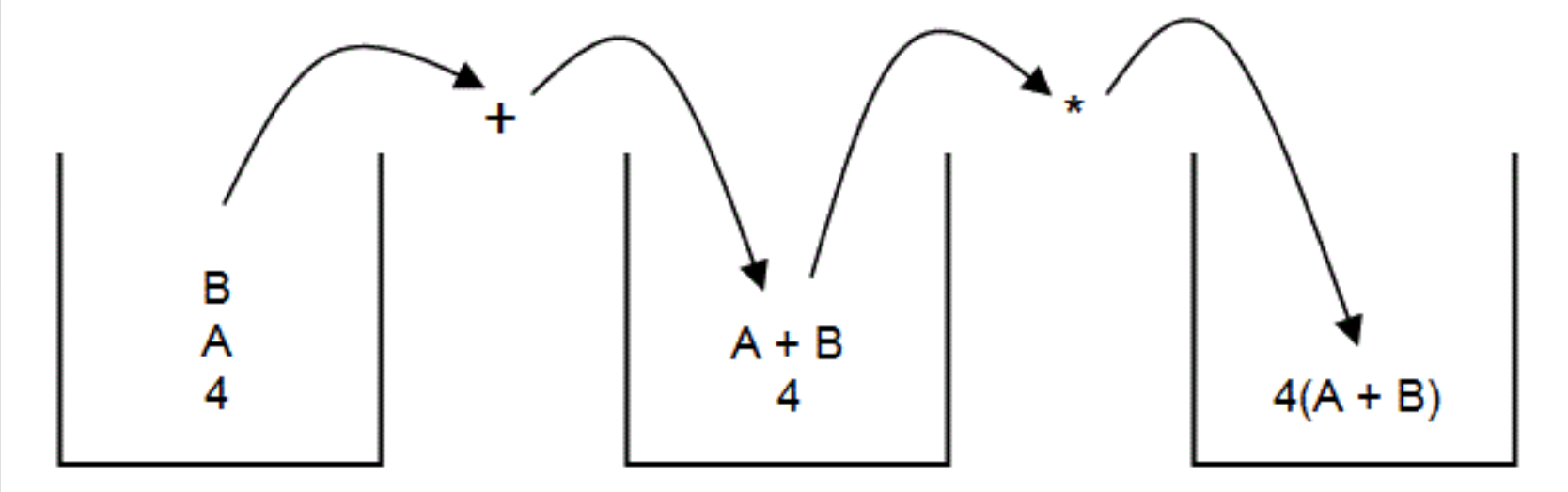
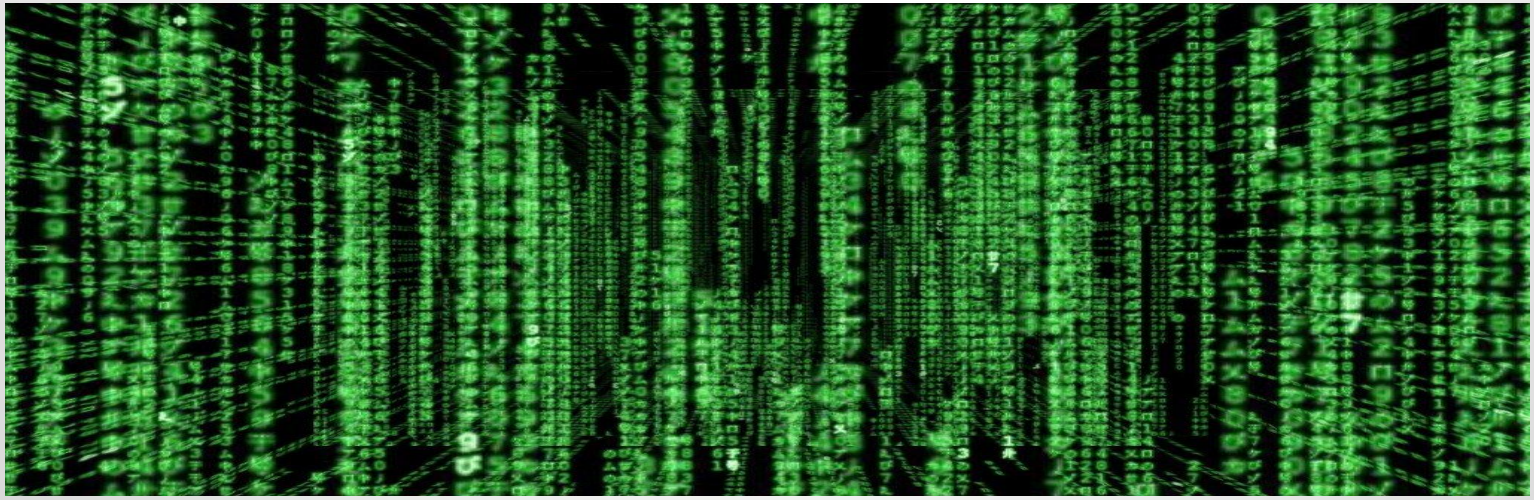


image from: http://www.theteacher.info/websites/ocr/WebPages/F453_Advanced/ConvertPolish/ConvertPolish.html

Here is a demonstration of the stacks for the operation 4(A+B).

Lab 1- Display

- Number appears on right side
- Create a counter to keep track of negative



Lab 1

```
void display(int num)
{
    clearScreen(); //gets rid of any current values on the screen
    int temp = num;
    const int ASCII = 48; // the ASCII value of 0 to be able to use numbers as chars
    int i = 0; // used for index
    int remainder = 0; // holds a single digit
    // If the number is 0, print it out and exit
    if (temp == 0){
        lcd_put_char7('0', 11);
        return;
    }
     // Turns a negative number into a positive number
    if (num < 0)
        num = -num;
    while(num!=0)
    {
         remainder = num % 10; // the last digit of num
         lcd_put_char7(remainder + ASCII, 11-i); // places digit in rightmost available index
         num = num/10; // Divides number by 10 for the next iteration
         i++;
    }
   // If the original number is negative, place a minus sign at the index immediately to the left of the first
digit
    if (temp < 0)
        lcd_put_char7('-', 11-i);
}
```

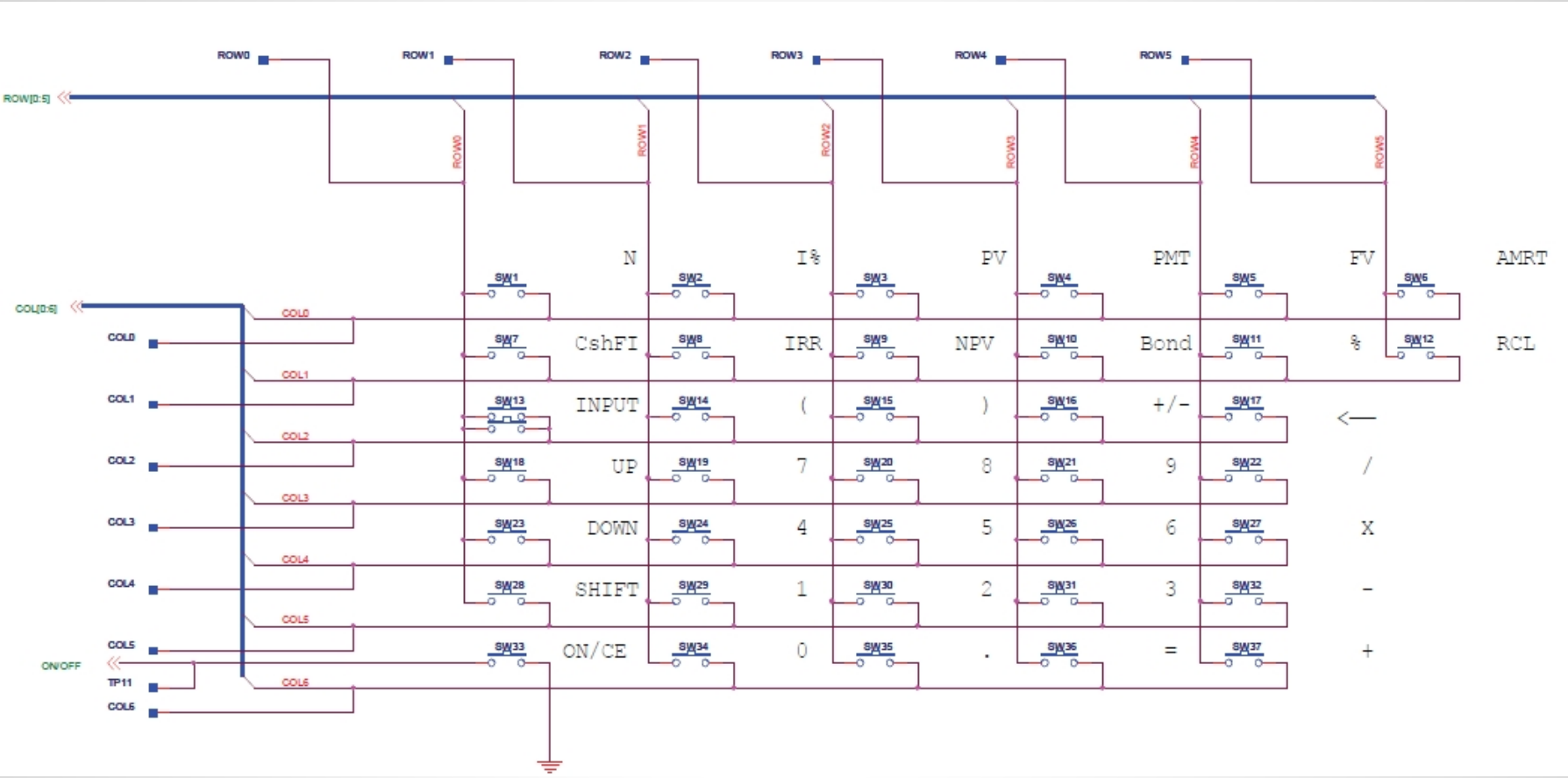
Lab 2

To figure out what is pressed:

- Set all columns high
- Set column you want to test low
- Loop through rows. If a row is low, that is the button being pressed
- The pressed key's row and column numbers are returned

Other implementations:

- 2d matrix for integers
- Defined operations above the 2d matrixes


ROW0
ROW1
ROW2
ROW3
ROW4
ROW5
ROW[0:5]
COL[0:5]
COL0
COL1
COL2
COL3
COL4
COL5
COL6
ON/OFF
TP11
N
I%
PV
PMT
FV
AMRT
CshFI
IRR
NPV
Bond
%
RCL
INPUT
(
)
+/-
<—
UP
7
8
9
/
DOWN
4
5
6
X
SHIFT
1
2
3
-
ON/CE
0
.
=
+

Lab 2- Finding Pressed Keys

```
int keyboard_key()
{
    int c =  0;
    int r = 0;

    for(c; c<7; c++)
    {
        r = 0;
        keyboard_column_low(c);
        for(r; r<6; r++)
        {
            if(!keyboard_row_read(r))
            {
                return key[c][r];
            }
        }
        keyboard_column_high(c);
    }
    return NOTHING; // Nothing pressed
}
```

Lab 2- Other

```
#define X 99 // Nothing important is pressed
// The following buttons are pressed
#define INPUT 16
#define NEGATE 19
#define RETURN 20
#define DIVIDE 15
#define MULTIPLY 14
#define SUBTRACT 13
#define PLUS 12
#define EQUALS 11

//2D matrix representing the rows and columns of the keyboard
int const key[7][6] = {
    {X,X,X,X,X,X},
    {X,X,X,X,X,X},
    {INPUT, X, X, NEGATE, RETURN, X},
    {X, 7, 8, 9, DIVIDE, X},
    {X, 4, 5, 6, MULTIPLY, X},
    {X, 1, 2, 3, SUBTRACT, X},
    {X, 0, X, EQUALS, PLUS, X}
    };
```

Lab 3 - Storing number and operation

- Used a boolean to differentiate between a number and a function being pressed
- The number and operation pressed are stored in a structure
- If the +/- key is pressed, a variable that is initially 1 is multiplied by -1, then later the number is multiplied by that variable
- If no number is pressed before an operation is pressed, the max integer is returned.
- Numbers that are entered are printed on screen as they are pressed

Lab 3

```
void keyboard_get_entry(struct entry *result)
{
    int num_pressed = 0; //boolean to see if an operation was pressed before a number
    int pos = 1; //determines if number is positive or negative: mult by -1 when +/- is
pressed
    int tempOp = ' ';
    result->operation = ' '; //Initially no operation
    result->number = 0;
    int keyPressed; //Stores the current key being pressed
    while(((*result).operation == ' ')) //While operation + input has not been pressed
    {
        keyPressed = keyboard_key();
        if(keyPressed == NEGATE) //toggle sign of the number
            pos *= -1;
        if(keyPressed >= 0 && keyPressed < 10 && (*result).number < INT_MAX / 10)
//number is being pressed
        {
            result->number = (*result).number * 10 + keyPressed;
            num_pressed = 1; // a number has been pressed
        }
```

```
else if (keyPressed >= PLUS && keyPressed <= DIVIDE) //operation being pressed
	{
		tempOp = keyPressed; //store operation
	}
	if(keyPressed == INPUT){
		result->operation = tempOp; //only set the operation once input has been pressed
		if(num_pressed == 0) //no number has been pressed
			result->number = INT_MAX;
		else
			result->number = (*result).number * pos;
	}
	if((*result).number != INT_MAX)
		lcd_print_int((*result).number);
	else if ((*result).number == INT_MAX){
		lcd_put_char7('M',9);
		lcd_put_char7('A',10);
		lcd_put_char7('X',11);
	}
}
```

Lab 4

- One pointer to the open space in an array with the lowest index
  - used to emulate a stack, in which numbers, both inputted and calculated are stored
  - to stay true to the original implementation of the calculator, the array has a size of 4

- +, -, *, and / functions implemented
  - when a function is pressed, the operation is immediately applied to the two numbers nearest to the stack pointer

keyboard_get_entry is changed to accommodate a number and input being pressed without an operation pressed

```
else if (keyPressed >= INPUT && keyPressed <= DIVIDE) //operation being pressed
	{
		result->operation = keyPressed;
		if(num_pressed == 0) //no number has been pressed
			result->number = INT_MAX;
		else
			result->number = (*result).number * pos;
	}
```

Populating stack and executing operations:

In main.c:

```
int stack[6];
int stack_size = 0;

while(stack_size < 6){
        keyboard_get_entry(&entry);
        if(entry.number != INT_MAX)
        {
                stack[stack_size] = entry.number;
                stack_size++;
        }
        if(entry.operation != INPUT)
                executeOp(entry.operation, stack,
                stack_size);
        }
```

```
void executeOp(int op, int stack[], int stack_size)
{
    int num1 = stack[stack_size-2];
    int num2 = stack[stack_size-1];

    int result = 0;
    if (op == PLUS)
        result = num1+num2;
    else if (op == SUBTRACT)
        result = num1-num2;
    else if (op == MULTIPLY)
        result = num1*num2;
    else if (op == DIVIDE)
        result = num1/num2;
    stack_size--;
    stack[stack_size] = result;
    lcd_print_int(result);

}
```

Skills Gained

- Ability to communicate semi-effectively
- Dividing problems into independent chunks
- Integration of hardware and software
- Working with colleagues who possess varying levels of programming skill
- Check your wires!