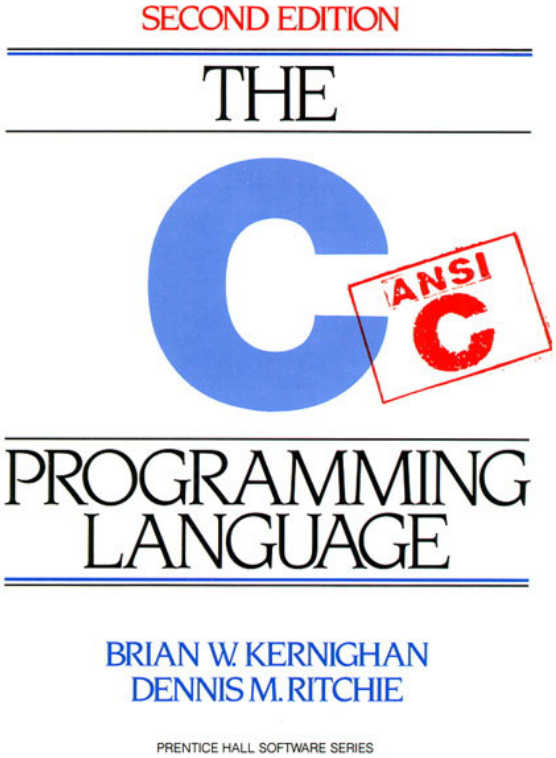
COMPUTER SCIENCE PROJECT

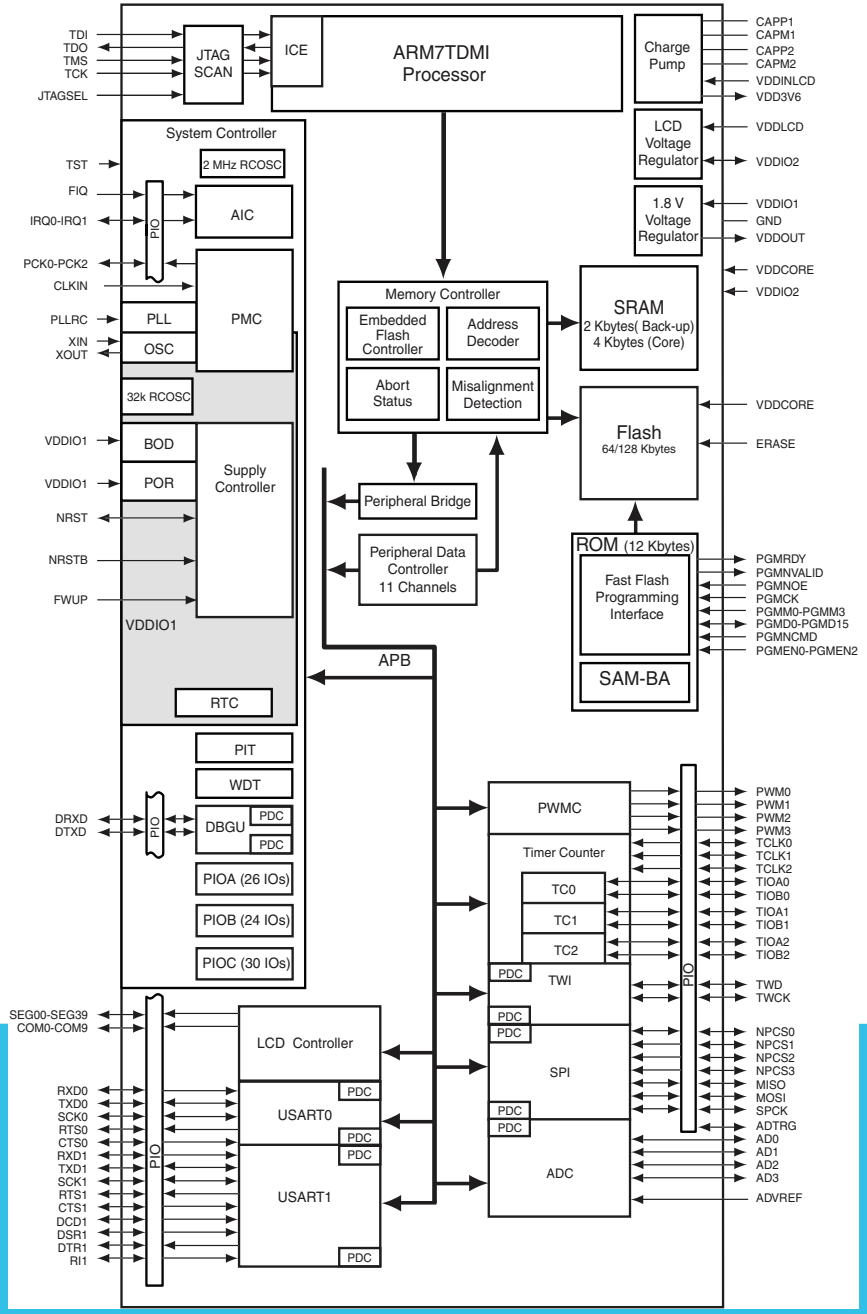
BUILDING AN HP CALCULATOR

OVERVIEW

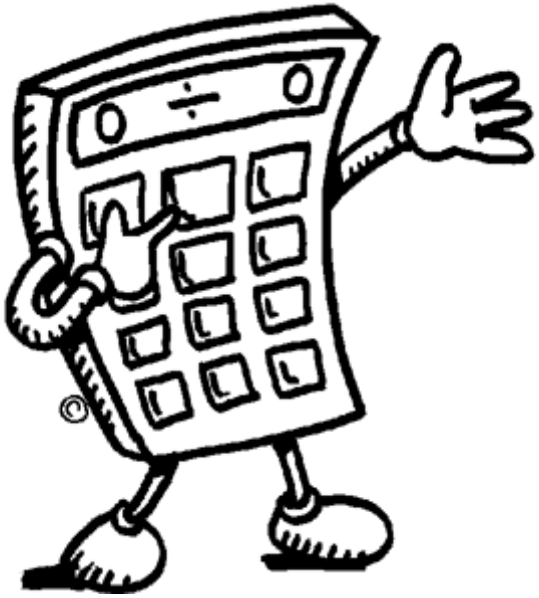
- Wrote firmware for an HP 20b calculator, allowing it to display user input and process information
- Worked with and understood the C programming language
- Went from modifying a simple method (lcd_put_char7) to working with control structures, structs, and pointers
- Instead of simply learning the syntax of C in a traditional classroom setting, we learned how to use Computer Science to affect society (i.e. alter what a widely-used device does)
- Took our first step in building applications
- Series of three lab experiments that took us from understanding display, to understanding how a keyboard works, to modifying the behavior of the calculator



PROCESSOR


TDI
TDO
TMS
TCK
JTAGSEL
JTAG SCAN
ICE
ARM7TDMI Processor
Charge Pump
CAPP1
CAPM1
CAPP2
CAPM2
VDDINLCD
VDD3V6
LCD Voltage Regulator
VDDLCD
VDDIO2
1.8 V Voltage Regulator
VDDIO1
GND
VDDOUT
VDDCORE
VDDIO2
System Controller
TST
FIQ
IRQ0-IRQ1
PCK0-PCK2
CLKIN
PLLRC
XIN
XOUT
2 MHz RCOSC
AIC
PIO
PMC
PLL
OSC
32k RCOSC
VDDIO1
BOD
VDDIO1
POR
NRST
NRSTB
FWUP
Supply Controller
VDDIO1
RTC
Memory Controller
Embedded Flash Controller
Address Decoder
Abort Status
Misalignment Detection
SRAM
2 Kbytes(Back-up)
4 Kbytes (Core)
Flash
64/128 Kbytes
VDDCORE
ERASE
Peripheral Bridge
Peripheral Data Controller
11 Channels
ROM (12 Kbytes)
Fast Flash Programming Interface
SAM-BA
PGMRDY
PGMNVALID
PGMNOE
PGMCK
PGMM0-PGMM3
PGMD0-PGMD15
PGMNCMD
PGMEN0-PGMEN2
APB
PIT
WDT
DRXD
DTXD
DBGU
PDC
PDC
PIOA (26 IOs)
PIOB (24 IOs)
PIOC (30 IOs)
PWMC
Timer Counter
TC0
TC1
TC2
PDC
TWI
PDC
PDC
SPI
PDC
PDC
ADC
PIO
PWM0
PWM1
PWM2
PWM3
TCLK0
TCLK1
TCLK2
TIOA0
TIOB0
TIOA1
TIOB1
TIOA2
TIOB2
TWD
TWCK
NPCS0
NPCS1
NPCS2
NPCS3
MISO
MOSI
SPCK
ADTRG
AD0
AD1
AD2
AD3
ADVREF
SEG00-SEG39
COM0-COM9
LCD Controller
PDC
USART0
PDC
PDC
USART1
PDC
RXD0
TXD0
SCK0
RTS0
CTS0
RXD1
TXD1
SCK1
RTS1
CTS1
DCD1
DSR1
DTR1
RI1
PIO

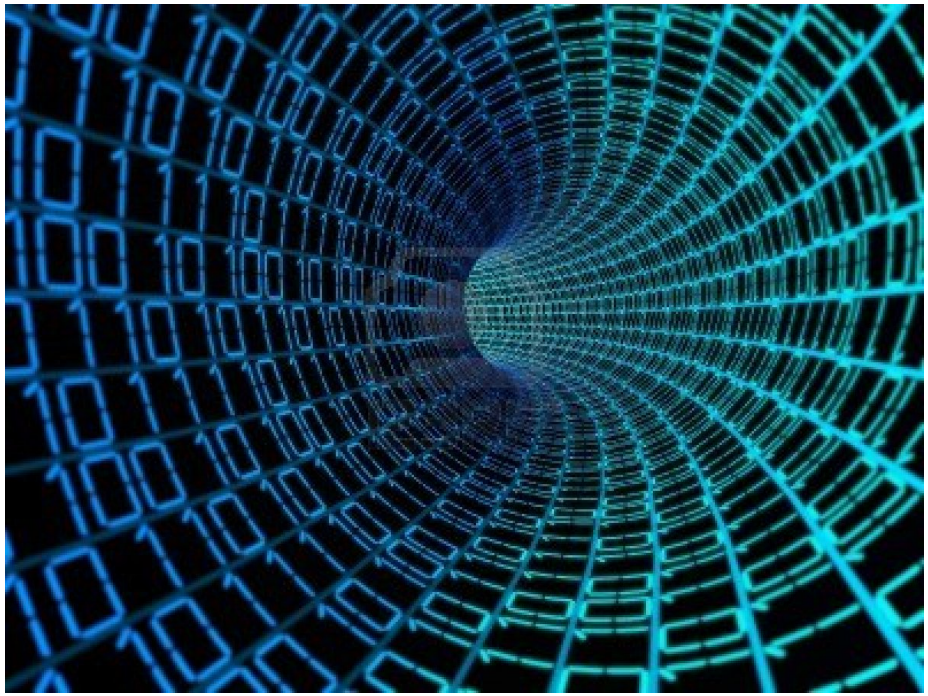
HOW RPN CALCULATORS WORK



- The calculator is an RPN calculator, which stands for Reverse Polish Notation.
- You can represent anything mathematically with- out using parentheses and by saving keystrokes. The style of an RPN calculator, however, is not conventional.
- When entering computations, you must put in the first numerical value and then press INPUT. Then you enter a second value and an operation. The result is you get an evaluated mathematical expression. Thus, putting in a 5, INPUT, 6, + will return a value of 11. This is counter-intuitive to us because we want to do 5, +, 6, =. However, this is actually more efficient.
- For complex situations like evaluating (3 + 5)/(7 + 6), you would divide them into sub-expressions and then divide the two sub-expressions at the very end. So you would enter a sequence of commands identical to 3, INPUT, 5, +, 7, INPUT, 6, +, /. Notice that the division operator is at the end. Running this in your calculator will actually return the correct value of 0.6153846.

A LITTLE BIT OF BACKGROUND

- The software used for the HP 20b calculator is based on entry- system logic, which contains RPN and Algebraic and Chain Algebraic software. There are over 220 built-in functions and menus and prompts are included.
- Atmel AT91SAM7L128 processor
- The *lcd_put_char7* function is the essential tool to display output on the calculator. The function takes in two parameters, the first one a character and the second one a number. The function then returns the character at the given index numerical value.



LAB 1 CODE

```
#include "AT91SAM7L128.h"
#include "lcd.h"

void clearScreen() {
    int i;
    for(i=0; i<11; i++){
        lcd_put_char7(' ',i);}
}

void printOutput(int number) {
    clearScreen();

    int counter, remain; char character;
    int position = 11;
    int absArg = abs(number);

    for(counter = absArg; counter >= 1; counter /= 10) {
        remain = counter % 10;
        character = '0' + remain;
        lcd_put_char7(character, position);
        position--;
    }

    if(number < 0) {
        lcd_put_char7('-', 0);
    }

    if(number == 0) {
        lcd_put_char7('0', 11);
    }
}

int main()
{
  lcd_init();

    printOutput(23444);
    printOutput(-0);

  return 0;
}
```

LAB 1 EXPLANATION

- Goal: display a numerical argument in the calculator
- Clear screen assigns empty spaces in every position in the screen. So it makes the screen ready to accept the number.
- After cleaning up the screen the variable takes the absolute value of input number. In the for loop, the number is kept divided by 10 and the remainder is stored in the right most position until the computer gets the one digit value of the highest digit number. For example, when you enter 205, the first result from for loop is 5 and it is shown in the right most position 11. And the remaining number 20 goes through the same process and 0 in position 10 and 2 in position 9. In case when the input number is negative, the number goes through the same process because the code takes the absolute value of the number prior to the for loop.
- To deal with the negative sign, lcd_put_char7('-', 0) displays '-' in the left most position. Also, if input is zero, the screen shows 0 in the rightmost position by lcd_put_char7('0', 11)

LAB 2 CODE

```
char keyboard_key()
{
    int i;

    char keyboard[7][6] = {{'X', 'X', 'X', 'X', 'X', 'X'},
        {'X', 'X', 'X', 'X', 'X', 'X'},
        {'I', '(', ')', 'O', '<'},
        {'^', '7', '8', '9', '%'},
        {'v', '4', '5', '6', 'x'},
        {'s', '1', '2', '3', '-'},
        {' ', '0', '.', '=', '+'}};

    for (i = 0; i < 7; i++)
    {
        keyboard_column_high(i);
    }

    int j, k;
    for (j = 0; j < 7; j++)
    {
        keyboard_column_low(j);
        for (k = 0; k < 6; k++)
        {
            if (!keyboard_row_read(k))
            {
                return keyboard[j][k];
            }
        }
        keyboard_column_high(j);
    }

    return ' ';

}
```

LAB 2 EXPLANATION

- Keyboard_key() works as follows: you first loop through all of the columns and you set them all to high. Initially you assume the worst (i.e. that the value you are trying to access is not in the calculator's keyboard). Thus, the rowPosition is set to two and the colPosition is set to five. You then loop through all of the rows for each column. If the row is also low, then you have to return both the value of the row and the value of the column.
- We then created a three-dimensional array of all of the possible input values on a calculator and we return the element in that three-dimensional array that has a row position and a column position equal to that of the two low values.
- This function shown is invoked by main.c and is located inside of the keyboard.c file.
- We tested it with a wide range of values. We saw what would happen if you kept pushing down the button (it would keep displaying) and we saw what would happen if you tried to hit two values (only one would be displayed). Thus, we accounted for error.

LAB 3 CODE/EXPLANATION

```
void keyboard_get_entry(struct entry *result)
        {

            int entry=0;

            int negative = 0;


  for (;;) {

//make some loop that calls keyboard_key() to check if it is true so as to see if whether a key is being pressed.  While a key
        is pressed keep looping through and calling keyboard_key() until it is no longer being pressed, so once keyboard_key()
        is no longer true and then take that value.  Every instance of keyboard_key() should be replaced by a variable initialized
        within the loop

            if (keyboard_key() >= 0 && keyboard_key() <= 9)
            {
                entry= entry * 10 + (keyboard_key() – '0');

                result->number = negative ? -entry : entry;

            }

//check the cases that can be pushed

    else if (keyboard_key() == '~') //if the plus minus sign is pushed, make negative true.

{

                    negative = 1;

        }
```

LAB 3 CODE/EXPLANATION PART TWO

```
 else if (keyboard_key() == '\r' || keyboard_key()  == '+' || keyboard_key()  == '-' || keyboard_key()  == '*' ||
        keyboard_key()  == '/') // if one of these are pressed exit and return what is in the pointer
            {
                    result->operation = keyboard_key();
        return;
    }
lcd_print_int_neg(negative, entry);
}
```

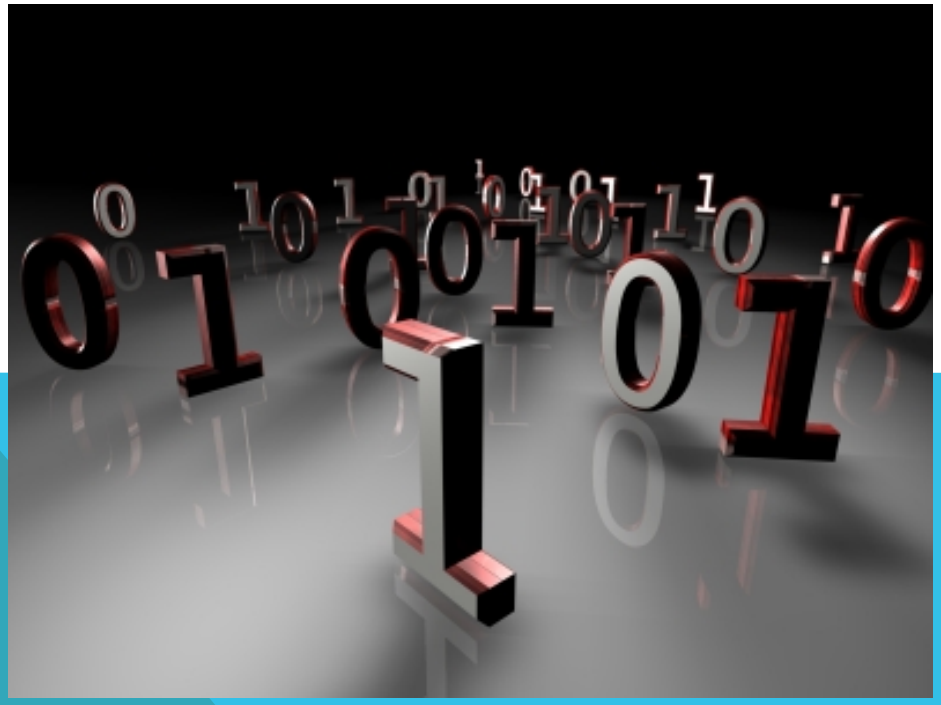
The user is going to enter a string of numbers which create one large number by looping through some sort of display modification where the numbers stay on the screen and allow for the addition of other numbers

When you have finished typing the number that you desire, you enter an operation. the program recognizes this operation and it returns the function, storing the operation and the number in struct

These are passed to the main function where you can test that this works correctly by displaying the number and the operation

LESSONS LEARNED

- Make sure that everyone in the team knows their role in the group. If someone has extensive experience with C, have them explain to the other group members what they have learned so they are caught up-to-speed. Leave no group member behind. Have no group member do all of the work.
- The code reviews were really helpful. The feedback was very good and we learned a lot about minimizing code and making code more readable while maintaining overall function.
- Also learned about the balance of commenting a program thanks to feedback



THE TEAM

Ga Young Lee (gl2429)

Noah Stebbins (nes2137)

Nicholas Sun (ns2874)

Bert Ramirez (lar2195)