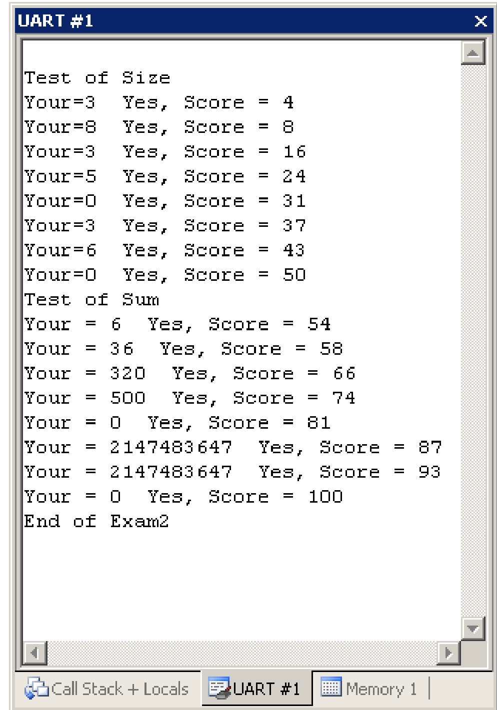
First:________________ Last:______________________



Scoring The correct output values are shown in the figure on the right. Your grade will be based both on the numerical results returned by your program and on your programming style. In particular, write code that is easy to understand, easy to debug, easy to change. Please employ good labels, pretty structure, and good comments.

Performance Score= Run by TA at the checkout		TA:

I promise to follow these rules

This is a closed book exam. You must develop the software solution using the **Keil uVision** simulator. You have 35 minutes, so allocate your time accordingly. You are allowed to bring only some pencils (no books, laptops, cell phones, hats, disks, CDs, or notes). You will have to leave other materials up front. Each person works alone (no groups). You have full access to **Keil uVision**, with the **Keil uVision** help. You may use the Window's calculator. You sit in front of a computer and edit/assemble/run/debug the programming assignment. You do NOT have access the book, internet or manuals. You may not take this paper, scratch paper, or rough drafts out of the room. You may not access your network drive or the internet. You are not allowed to discuss this exam with other EE319K students until Thursday.

The following activities occurring during the exam will be considered scholastic dishonesty:

1) running any program from the PC other than **Keil uVision**, or a calculator,
2) communicating with other students by any means about this exam until Thursday,
3) using material/equipment other than a pen/pencil.

Students caught cheating will be turned to the Dean of Students.

Signed: ______________________ October 31, 2012

Procedure

First, you will log onto the computer and download files from the web as instructed by the TAs.

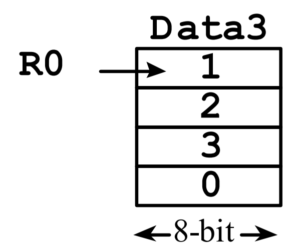
Web site xxxxxx
user: xxxxxx
password: xxxxxx

Unzip the folder placing it in a temporary folder. You are not allowed to archive this exam. Within **Keil uVision** open these files, put your name on the first comment line of the file **Exam2.s**. Before writing any code, please assemble and run the system. You should get output like the figure above (but a much lower score). You may wish create backup versions of your program. If you wish to roll back to a previous version, simply open one of the backup versions.

My main program will call your subroutines multiple times, and will give your solution a performance score of 0 to 100. *You should not modify my main program or my example data.* When you have written your subroutines, you should run my main program, which will output the results to the **`UART#1`** window. After you are finished, raise your hand and wait for a TA. The TA will direct you on how to complete the submission formalities. The TA will run your program in front of you and record your performance score on your exam cover sheet. The scoring page will not be returned to you. The submission guidelines are at the end of the exam handout.

Part a) The first subroutine, called **`Size`**, determines the number of signed 8-bit data values in an array. The same array format will be used for the first and second subroutines. The array contains a list of 8-bit signed nonzero integers. Each entry occupies one 8-bit byte, such that entries are located at sequential memory addresses. The array terminates with a zero. *The zero itself is NOT one of the data points*. Look at the source code to see all six sets of test data. E.g.,

```
Data3 DCB 1,2,3,0  ; Size=3
```



Input parameter: A pointer to the array is passed into your program in R0.
Output parameter: The number of data values returned in R0.
Error conditions: none.

A typical calling sequence is

```
  LDR R0,=Data3 ; pointer to the array Data3
  BL  Size      ; should return R0=3
```

Part b) Write a subroutine, called **`Sum`**, which will add the values of an array of 8-bit signed numbers to form a 32-bit sum. The array is terminated by a zero value. The sum is returned as R0. If any element of the array is < 0, return 0x7FFFFFFF. You may assume overflow will not occur on addition.

Input parameter: A pointer to the array is passed into your program in R0.
Output parameter: The 32-bit sum is returned in R0.
Error conditions: Return RegA≠ 0 on signed overflow, and RegA= if the sum is valid.

A typical calling sequence is

```
  LDR R0,=Data3 ; pointer to the array Data3
  BL  Sum       ; should return R0=6 (1+2+3)
```

Your subroutines should work for all cases shown in the starter file. We will give you data for which the order of operation will not matter. I.e., the sum of the numbers in **`Data3`** will always be 6 regardless of the order in which the data are added together. The array may be empty (and your program should return R0=0).

<u>Submission Guidelines</u>:

- Log onto Blackboard and submit your Exam2.s source file into the Exam2 field. Be careful because only one submission will be allowed.

Memory access instructions
```
LDR    Rd, [Rn]        ; load 32-bit number at [Rn] to Rd
LDR    Rd, [Rn,#off]   ; load 32-bit number at [Rn+off] to Rd
LDR    Rd, =value      ; set Rd equal to any 32-bit value (PC rel)
LDRH   Rd, [Rn]        ; load unsigned 16-bit at [Rn] to Rd
LDRH   Rd, [Rn,#off]   ; load unsigned 16-bit at [Rn+off] to Rd
LDRSH  Rd, [Rn]        ; load signed 16-bit at [Rn] to Rd
LDRSH  Rd, [Rn,#off]   ; load signed 16-bit at [Rn+off] to Rd
LDRB   Rd, [Rn]        ; load unsigned 8-bit at [Rn] to Rd
LDRB   Rd, [Rn,#off]   ; load unsigned 8-bit at [Rn+off] to Rd
LDRSB  Rd, [Rn]        ; load signed 8-bit at [Rn] to Rd
LDRSB  Rd, [Rn,#off]   ; load signed 8-bit at [Rn+off] to Rd
STR    Rt, [Rn]        ; store 32-bit Rt to [Rn]
STR    Rt, [Rn,#off]   ; store 32-bit Rt to [Rn+off]
STRH   Rt, [Rn]        ; store least sig. 16-bit Rt to [Rn]
STRH   Rt, [Rn,#off]   ; store least sig. 16-bit Rt to [Rn+off]
STRB   Rt, [Rn]        ; store least sig. 8-bit Rt to [Rn]
STRB   Rt, [Rn,#off]   ; store least sig. 8-bit Rt to [Rn+off]
PUSH   {Rt}            ; push 32-bit Rt onto stack
POP    {Rd}            ; pop 32-bit number from stack into Rd
ADR    Rd, label       ; set Rd equal to the address at label
MOV{S} Rd, <op2>       ; set Rd equal to op2
MOV    Rd, #im16       ; set Rd equal to im16, im16 is 0 to 65535
MVN{S} Rd, <op2>       ; set Rd equal to -op2
```
Branch instructions
```
B    label   ; branch to label    Always
BEQ  label   ; branch if Z == 1   Equal
BNE  label   ; branch if Z == 0   Not equal
BCS  label   ; branch if C == 1   Higher or same, unsigned ≥
BHS  label   ; branch if C == 1   Higher or same, unsigned ≥
BCC  label   ; branch if C == 0   Lower, unsigned <
BLO  label   ; branch if C == 0   Lower, unsigned <
BMI  label   ; branch if N == 1   Negative
BPL  label   ; branch if N == 0   Positive or zero
BVS  label   ; branch if V == 1   Overflow
BVC  label   ; branch if V == 0   No overflow
BHI  label   ; branch if C==1 and Z==0  Higher, unsigned >
BLS  label   ; branch if C==0 or  Z==1  Lower or same, unsigned ≤
BGE  label   ; branch if N == V   Greater than or equal, signed ≥
BLT  label   ; branch if N != V   Less than, signed <
BGT  label   ; branch if Z==0 and N==V  Greater than, signed >
BLE  label   ; branch if Z==1 and N!=V  Less than or equal, signed ≤
BX   Rm      ; branch indirect to location specified by Rm
BL   label   ; branch to subroutine at label
BLX  Rm      ; branch to subroutine indirect specified by Rm
```
Interrupt instructions
```
CPSIE  I              ; enable interrupts  (I=0)
CPSID  I              ; disable interrupts (I=1)
```

Logical instructions
```
AND{S} {Rd,} Rn, <op2> ; Rd=Rn&op2    (op2 is 32 bits)
ORR{S} {Rd,} Rn, <op2> ; Rd=Rn|op2    (op2 is 32 bits)
EOR{S} {Rd,} Rn, <op2> ; Rd=Rn^op2    (op2 is 32 bits)
BIC{S} {Rd,} Rn, <op2> ; Rd=Rn&(~op2) (op2 is 32 bits)
ORN{S} {Rd,} Rn, <op2> ; Rd=Rn|(~op2) (op2 is 32 bits)
```

```
LSR{S} Rd, Rm, Rs      ; logical shift right Rd=Rm>>Rs  (unsigned)
LSR{S} Rd, Rm, #n      ; logical shift right Rd=Rm>>n   (unsigned)
ASR{S} Rd, Rm, Rs      ; arithmetic shift right Rd=Rm>>Rs (signed)
ASR{S} Rd, Rm, #n      ; arithmetic shift right Rd=Rm>>n  (signed)
LSL{S} Rd, Rm, Rs      ; shift left Rd=Rm<<Rs (signed, unsigned)
LSL{S} Rd, Rm, #n      ; shift left Rd=Rm<<n  (signed, unsigned)
```

Arithmetic instructions

```
ADD{S} {Rd,} Rn, <op2> ; Rd = Rn + op2
ADD{S} {Rd,} Rn, #im12 ; Rd = Rn + im12, im12 is 0 to 4095
SUB{S} {Rd,} Rn, <op2> ; Rd = Rn - op2
SUB{S} {Rd,} Rn, #im12 ; Rd = Rn - im12, im12 is 0 to 4095
RSB{S} {Rd,} Rn, <op2> ; Rd = op2 - Rn
RSB{S} {Rd,} Rn, #im12 ; Rd = im12 – Rn
CMP    Rn, <op2>       ; Rn – op2      sets the NZVC bits
CMN    Rn, <op2>       ; Rn - (-op2)   sets the NZVC bits
MUL{S} {Rd,} Rn, Rm    ; Rd = Rn * Rm       signed or unsigned
MLA    Rd, Rn, Rm, Ra  ; Rd = Ra + Rn*Rm    signed or unsigned
MLS    Rd, Rn, Rm, Ra  ; Rd = Ra - Rn*Rm    signed or unsigned
UDIV   {Rd,} Rn, Rm    ; Rd = Rn/Rm         unsigned
SDIV   {Rd,} Rn, Rm    ; Rd = Rn/Rm         signed
```

Notes `Ra Rd Rm Rn Rt represent 32-bit registers`

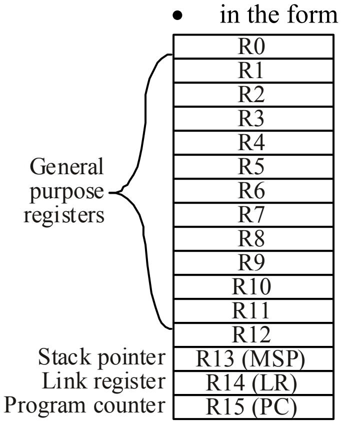
```
value   any 32-bit value: signed, unsigned, or address
{S}     if S is present, instruction will set condition codes
#im12   any value from 0 to 4095
#im16   any value from 0 to 65535
{Rd,}   if Rd is present Rd is destination, otherwise Rn
#n      any value from 0 to 31
#off    any value from -255 to 4095
label   any address within the ROM of the microcontroller
op2     the value generated by <op2>
```

Examples of flexible operand **<op2>** creating the 32-bit number. E.g., **Rd = Rn+op2**

```
ADD Rd, Rn, Rm         ; op2 = Rm
ADD Rd, Rn, Rm, LSL #n ; op2 = Rm<<n  Rm is signed, unsigned
ADD Rd, Rn, Rm, LSR #n ; op2 = Rm>>n  Rm is unsigned
ADD Rd, Rn, Rm, ASR #n ; op2 = Rm>>n  Rm is signed
ADD Rd, Rn, #constant  ; op2 = constant
```

, where **X** and **Y** are hexadecimal digits:

- produced by shifting an 8-bit unsigned value left by any number of bits
- in the form **0x00XY00XY**
- in the form **0xXY00XY00**
- in the form **0xXYXYXYXY**



Condition code bits

N negative
Z zero
V signed overflow
C carry or unsigned overflow