Von-Newman vs. Harvard Architecture

Von-Newman has a single memory space, share for data and program instructions. Harvard Architecture has separate memory spaces for data and instructions (so you cannot execute from the data memory).

2's compliment

00000000	0
00000001	1
...	...
01111110	126
01111111	127
10000000	−128
10000001	−127
10000010	−126
...	...
11111110	−2
11111111	−1

It is important to know that the hardware does all arithmetic in 2's compliment. It is up to the programmer to interpret the number as signed or unsigned.

To convert a number from 2's compliment, for example -45 in 2's compliment is 11010011, we can do something like this,

To go the other way from say -1 to the 2's compliment form 11111111 we use that $2^p - X$ formula. I'm not exactly sure how its supposed to work so I've hacked it to make it work.

If the number you wish to convert is negative, let $X = -n$, so that X is positive then take 2^p where *p* is the number of bits you are using (say 8), then subtract X. If the number to convert is less than 2^p (where *p* is the number of bits, say 8) then leave it as is and that in your 2's compliment. Now that was complicated. But its the only way I can get that advertised $2^p - X$ formula to work with the given set of sample data (as in that table above).

Sign Extension

Why do we need sign extension? We need it in order to do operations on numbers than have different bit lengths (the number of bits used to represent the number).

Decimal to Binary

From a human kind of approach to convert 221 to binary, we see that $2^7 = 128$, that is 7 is the largest power of 2 less than 221, so we have 1×2^7. That gives us 128, so we still have 93 (221-128) to go. We try 2^6, this is less than 93. So far we have $1 \times 2^7 + 1 \times 2^6$. 29 left now, but 2^5 is greater

than 29, so we put a zero in that digit, ie. $1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5$. If we go on we get $1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$. Taking the coefficients of the $\times 2^x$ terms we get the number 221 in binary, 11011101.

We can convert hexadecimal to binary by going from hex to decimal then decimal to binary. For hex to decimal,

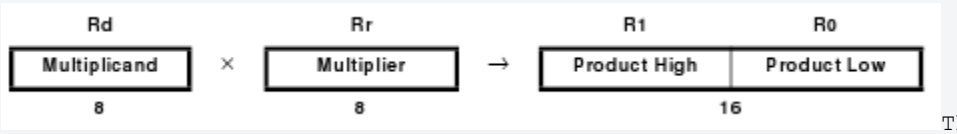
$$F23AC = 15 \times 16^4 + 2 \times 16^3 + 3 \times 16^2 + 10 \times 16^1 + 12 \times 16^0 = 992172$$

(where F23AC is in hex and 992172 is in decimal)

Operations on Signed and Unsigned Multi byte Numbers

```
add al, bl
adc ah, bh
does a + b, result in is a.
```

There are 3 multiplication operations, MUL (Multiply Unsigned), MULS (Multiply Signed) and MULSU (Multiply Signed with Unsigned). They each do this. Notice the result is stored in r1:r0.



Thus to do n*m = r

```
where n is 2 bytes unsigned and m is 1 byte signed,
mulsu nl, m ;nl * (signed)m
movw rh:rl, r1:r0
mulsu nh, m ;(signed)nh * m
add rh, r0
```

We can also do 16bit * 16bit,

```
;* From AVR Instruction Set Guide, pg 99-100.
;* Signed multiply of two 16-bit numbers with 32-bit result.
;* r19:r18:r17:r16 = r23:r22 * r21:r20
muls16x16_32:
clr r2
muls r23, r21 ;(signed)ah * (signed)bh
movw r19:r18, r1:r0
mul r22, r20 ;al * bl
movw r17:r16, r1:r0
mulsu r23, r20 ;(signed)ah * bl
sbc r19, r2
add r17, r0
adc r18, r1
adc r19, r2
mulsu r21, r22 ;(signed)bh * al
```

```
sbc r19, r2
add r17, r0
adc r18, r1
adc r19, r2
ret
```

brge and brsh

- brge is Branch if Greater or Equal, Signed.
  if ($N \oplus V = 0$) then branch.
  When you do cp Rd, Rr then brge, the branch will be taken if Rd $\geq$ Rr, where Rd and Rr are taken to be signed numbers.
- brsh is Branch if Same or Higher.
  if ($C = 0$) then branch.
  When you do cp Rd, Rr then brsh, the branch will be taken if Rd $\geq$ Rr, where Rd and Rr are taken to be unsigned numbers.

Calculating Total Stack Space Needed

Draw a call tree, find the path with the most total weight, that total weight is the total stack size needed. Here is the sample question,

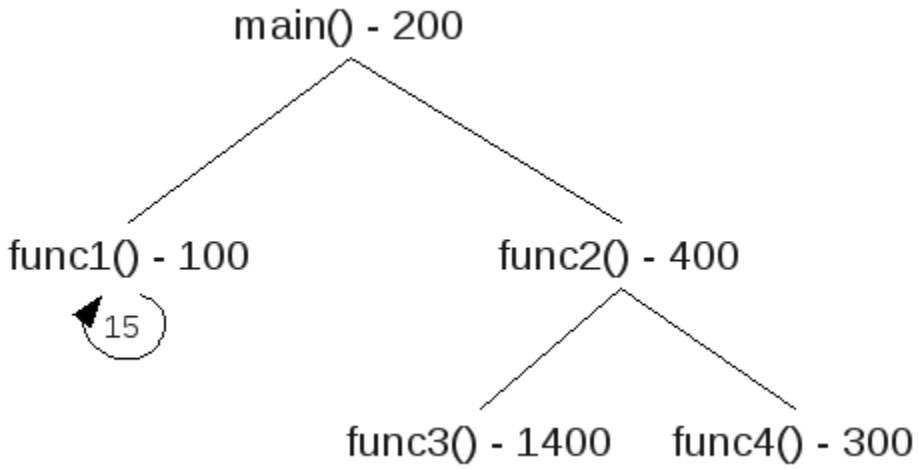
A C program consists of five functions. Their calling relations are shown as follows (the arguments and irrelevant C statements are omitted).

```
int main(void) {
  …
  func1(…);
  func2(…);
  …
}
int func1(…) {
  …
  func1(…);
  …
}

int func2(…) {
  …
  func3(…);
  func4(…);
  …
}
```

func1() is a recursive function and calls itself 15 times for the actual parameters given in main(). Both func3() and func4() do not call any function. The sizes of all stack frames are shown as follows.

main(): 200 bytes.
func1(): 100 bytes.
func2(): 400 bytes.
func3(): 1,400 bytes.
func4(): 300 bytes.
How much stack space is needed to execute this program correctly? (3 marks)



There are three paths,

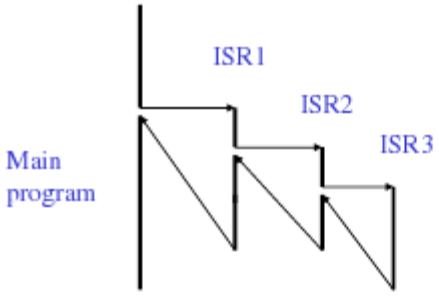
main() func1() func1() x 15 200+100+15×100 =1800	main() func2() func3() 200+400+1400 =2000	main() func2() func4() 200+400+300 =900

The path with the most total weight is main() > func2() > func3(), so this is the total stack space needed.

Nested Interrupts

Nested Interrupts

- Interrupt Service Routines can be interrupted by another interrupt.
- In AVR MCUs the interrupt service routine of an interrupt can be interrupted by another interrupt if the service routine includes the instruction sei.



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(Source: Hui Wu's Lecture Notes)

Keypads with 'abc' 'def' ... buttons

These keypads where to enter b you need to press the abc button twice in succession, but wait to long at it will chose a. Here is a psudo algorithm that seemed to fit this,

```
.def reg = rN
.def reg = rM
.def count = rX

//passvalue means that we register the given value ie. abc abc wait > b

setup:
clr reg (to some value that is != to a key value) ;set to default
clr count
rjmp keyloop

keyloop:
  check pins for a key
  if no key pressed rjmp keyloop, else continue
```

```
  //key was pressed, and value is stored in key
  reset someTimeCounter
  if (key == reg) {
     inc count
     if (count == 3)
        passvalue(reg,count)
  }else{
     if (reg != default) ;so we don't initially passvalue
        passvalue(reg,count) ;send the last value
     reg = key ;store the new one
     count = 1
  }

rjmp keyloop

if someTimeCounter expires and count != 0 //(count up, so expires after time to wait
for anymore keypresses) (check count != 0, because if its 0 then we never had any key
pressed that we need to send)
   passvalue(reg,count)
   reg = default
```

Switch Bounce Software Solution

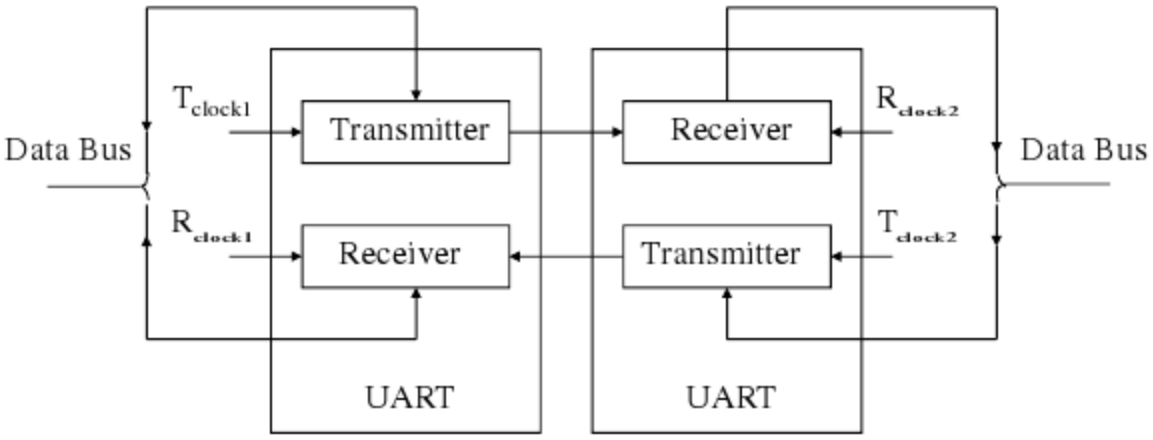
When a switch makes contact, its mechanical springiness will cause the contact to bounce, or make and break, for a few millisecond (typically 5 to 10 ms). Two software solutions are wait and see and counter-based.

1. If we detect it as closed, wait for a little bit and check again.
2. Poll the switch constantly. For each poll if the switch is closed increment the counter. If we reach a certain value in a certain time then the switch was closed (or button pressed).

Serial Communication (Start and Stop bit)

"[The] start bit is used to indicate the start of a frame. Without the start bit, the receiver cannot distinguish between the idle line and the 1 bit because both are logical one. A stop bit is used to allow the receiver to transfer the data from the receive buffer to the memory." (Wu, Homework 6 Solutions)

UART



(Source: Hui Wu, Lecture Notes)

Sample Q3a

(This code probably won't work and probably has errors (and maybe not just simple ones, but serious ones that mean that the logic is wrong))

```
.dseg
A: .byte 20 ;array of size 10, element size 2 bytes

.cseg
ldi XL, low(A)
ldi XH, high(A)

;add the contents of the array.
store 0
store 1
store 2
store 3
store 4
store 5
store 6
store 7
store 8
store 9

;find the largest value
ldi XL, low(A)
ldi XH, high(A)

;start with the 1st element of the array
```

```
ld r25, X+
ld r26, X+

ldi r20, 10 ;size of array
loop:
 cpi r20, 0
 breq endloop

 ld r21, X+
 ld r22, X+

 cp r25, r21
 cpc r26, c22
 brlo lowerthan
 ;we have a new max
 mov r25, r21
 mov r26, r22

 lowerthan:

 inc r20
 rjmp loop
endloop: rjmp endloop

.macro store
ldi r16, low(@0)
ldi r17, high(@0)

st X+, r16
st X+, r17
.endmacro
```

For some reason in my lecture notes I have “eg. fine 2nd or 3rd smallest or largest” so here is a modification to do something like that.

```
.dseg
A: .byte 20 ;array of size 10, element size 2 bytes

.cseg
```

```
ldi XL, low(A)
ldi XH, high(A)

;add the contents of the array.
store 0
store 1
store 2
store 3
store 4
store 5
store 6
store 7
store 8
store 9

;sort into accending
loopthough for the length of array, (by then we can be sure its sorted)
ldi r23, 10
largeloop:
 cpi r23, 0
 breq endlargeloop

 ;point X to the start of A
 ldi XL, low(A)
 ldi XH, high(A)

 ;start with the 1st element of the array
 ld r25, X+
 ld r26, X+

 ldi r20, 10 ;size of array
 loop:
 cpi r20, 0
 breq endloop

 ;the next value
 ld r21, X+
 ld r22, X+
```

```
 cp r25, r21
 cpc r26, c22
 brge gethan
 ;r22:r21 < r26:r25
 ;swap the order
 st -X, r26
 st -X, r25
 st -X, r22
 st -X, r21

 ld r24, X+ ;to change the X pointer
 ld r24, X+

 ld r25, X+
 ld r26, X+

 gethan:

 inc r20
 rjmp loop
 endloop:
endlargeloop:

inf: rjmp inf

.macro store
ldi r16, low(@0)
ldi r17, high(@0)

st X+, r16
st X+, r17
.endmacro
```

Source: http://andrewharvey4.wordpress.com/2009/06/23/comp2121-quick-summary-on-particular-aspects/