

C5 Solutions

1. Convert the following base 10 numbers into 8-bit 2's complement notation
0, -1, -12

To Compute 0

$$0 = 00000000$$

To Compute -1

Step 1. Convert 1 to binary
00000001

Step 2. Flip the bits
11111110

Step3. Add 1
11111111

Therefore **-1 = 11111111**

To Compute -12

Step 1. Convert 12 to binary
00001100

Step 2. Flip the bits
11110011

Step3. Add 1
11110100

Therefore **-12 = 11110100**

2. Perform each of the following additions assuming that the bit strings represent values in 2's complement notation. Identify the cases in which the answer is incorrect because of overflow.

$$\begin{array}{r} 1111 \\ + 1111 \\ \hline 11110 \end{array}$$

Answer = 11110

Overflow = 0

∴ Answer is correct

$$\begin{array}{r} 01111 \\ + 10001 \\ \hline 100000 \end{array}$$

Answer = 00000

Overflow = 1

∴ Answer is incorrect

$$\begin{array}{r} 01110 \\ + 01010 \\ \hline 11000 \end{array}$$

Answer = 11000

Overflow = 0

∴ Answer is correct

3. Write an algorithm to convert a negative decimal number into a binary number in 2's complement form. Assume that the number ranges from +127 to -128

1. If the number is less than 0
 - a. Multiply by -1
 - b. Flip the bits by 'number XOR 0xff'
 - c. Add 1 to the result
2. Convert the number into binary

Hint: You already know how to convert a positive decimal number into binary notation. Think about determining sign and inverting bit positions.

4. Implement your algorithm in Ada95. Turn in an electronic copy of your code listing and a hard copy of your code.

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Compiling: c:/docume~2/jk/desktop/16070/codeso~1/decimal_to_binary.adb (source file time stamp: 2003-09-17 11:09:18)

```
1. with Ada.Text_IO;
2. use Ada.Text_IO;
3.
4. with Ada.Integer_Text_IO;
5. use Ada.Integer_Text_IO;
6.
7. procedure Decimal_To_Binary is
8.
9.   -- bit-wise operations are only defined for modular types
10.  type byte is mod 256;
11.
12.  Number_To_Convert : integer;
13.  Place_Holder: Byte;
14.
15.  Binary_Number : String (1..8);
16.  Count : Integer :=8;
17.
18.
19. begin
20.   -- set the string to all zeroes
21.   Binary_Number := "00000000";
22.
23.   -- get the number to be converted
24.   Put("Please enter an integer :");
25.   Get(Number_To_Convert);
26.
27.   -- check if the number is negative. If it is,
28.   -- convert it into positive
29.   if Number_To_Convert < 0 then
30.
31.     Number_To_Convert := -1 * Number_To_Convert;
32.
```

```

33.  -- convert to modular type
34.  Place_Holder := Byte'Val(Integer'Pos(Number_To_Convert));
35.
36.  -- flip the bits
37.  Place_Holder := Place_Holder xor 2#11111111#;
38.  -- add 1
39.  Place_Holder := Place_Holder + 2#1#;
40.  -- reconvert to integer
41.  Number_To_Convert := Integer'Val(Byte'Pos(Place_Holder));
42.
43. end if;
44.
45. -- decimal to binary conversion
46. -- fill in the bit pattern from left to right
47. loop
48.   exit when Count = 0;
49.   -- if the remainder is non-zero, the bit is set to 1
50.   -- else the bit is 0
51.   if (Number_To_Convert mod 2) = 1 then
52.     Binary_Number(Count) := '1';
53.   else
54.     Binary_Number(Count) := '0';
55.   end if;
56.
57.   Count := Count - 1;
58.   Number_To_Convert := Number_To_Convert/2;
59.
60. end loop;
61.
62. Put(Binary_Number);
63.
64. end Decimal_To_Binary;
65.
66.
67.

```

67 lines: No errors

C6

1. How many bits do you need to represent a number in excess-16 format? What is the excess-16 representation of 12?

$$16 = 2^4 = 2^{N-1} \Rightarrow N = 5.$$

Five bits are needed to represent the number in excess-16 format.

Step 1. Add 16 to the number

$$16 + 12 = 28$$

Step 2. Convert to binary

$$12 \text{ in excess-16} = 11100$$

2. Convert $29/8$ into binary 8-bit floating-point representation.

Step1. Set the sign bit to zero since number is positive

Step2. Convert the number into binary representation

$$\begin{aligned} 29/8 &= 3 + 5/8 \\ &= 011.101 \end{aligned}$$

Step 3. Normalize the binary representation

$$0.11101 * 2^2$$

Step 4. Convert the exponent into excess-4

$$2 = 110$$

Step 5. Fill in the mantissa

$$\text{Therefore } 29/8 = 01101110$$

3. Sketch the basic von Neumann architecture and describe each component in a few lines.

The von Neumann architecture describes a computer with four main sections:

the Arithmetic and Logic Unit (ALU)

the control unit (CU)

the memory

the input and output devices (collectively termed I/O)

These parts are interconnected by a bundle of wires, a Bus.

The central processing unit (or CPU) is the part of a computer that interprets and carries out the instructions contained in the software. In most CPUs, this task is divided between a CU that directs program flow and one or more execution units that perform operations on data. Almost always, a collection of Registers is included to hold operands and intermediate results.

The ALU is one of the core components of all CPUs. It is capable of calculating the results of a wide variety of common computations. The most common available operations are the integer arithmetic operations of addition, subtraction, and multiplication, the bitwise logic operations of **and**, **not**, **or** and **xor**, and various shift operations. The ALU takes as inputs the data to be operated on and a code from the CU indicating which operation to perform, and for output provides the result of the computation. In some designs it may also take as input and output a set of condition codes, which can be used to indicate cases such as carry-in or carry-out, overflow, or other statuses.

The CU the part of a CPU or other device that directs its operation. The outputs of the unit control the activity of the rest of the device.

The memory is a sequence of numbered "cells", each containing a small piece of information. The information may be an **instruction** to tell the computer what to do. The cell may contain **data** that the computer needs to perform the instruction. Any slot **may contain either**, and indeed what is at one time data might be instructions later. In general, memory can be rewritten over millions of times - it is a scratchpad rather than a stone tablet.

The size of each cell, and the number of cells, varies greatly from computer to computer, and the technologies used to implement memory have varied greatly - from electromechanical relays, to mercury-filled tubes in which acoustic pulses were formed, to matrices of permanent magnets, to individual transistors, to integrated circuits with millions of capacitors on a single chip.

The bus is a bundle of wires that interconnect all the different parts of the computer.

4. Write an assembly language program (using the language described in the machine language handout) to add two positive numbers. Assume that the numbers are present in memory locations FEh and FFh. Turn in both a hard copy and an electronic copy of your code.

```
; Program to Add two positive numbers stored in FEh and FFh
; Programmer : Joe B
; Date Last Modified: September 15th 2003

load r1, [FEh] ; load number in FEh
load r2, [FFh] ;load the number in FFh
addi r3, r1,r2;perform the addition operation
store r3,[F0h]; store the result in F0h
halt; stop the program
```

C7

1. Write an algorithm to implement the subtraction operation for two positive integers in assembly language.
 1. Let the numbers be A, B and the operation be A-B
 2. Convert A into binary
 3. Convert B into binary
 4. Compute 2's complement of B
 - i. Invert the bits in B using B xor 11111111
 - ii. Add 1 to B
 5. Add A and the 2's complement of B.

2. Implement your algorithm in the assembly language describe in the machine language handout. Test your implementation using the SimpleSim simulator.

```
; Program name       : Subtraction using add only
;Programmer         : Joe B
;Last Modified      : Sep 16 2003

load  R1,1           ;1 added for computing 2's complement
load  R2,FFh         ;mask for flipping the bits
load  R3,first_number;
load  R4, second_number;
xor    R5, R4,R2      ; flip the 0's and 1's in the second number
addi   R5,R5,R1       ; add 1 to the flipped bits to get the 2's complement
addi   R5,R5,R3       ; add the numbers to obtain A - B
halt

first_number:        db 8  ;A in A-B
second_number:       db 5  ;B in A-B
```

T6 HOMEWORK SOLUTIONS (WAITZ)

(1 OF 2)

| A) LEG | Q | W | |
|--------|---|---|---|
| 1-2 | - | - | (ISOTHERMAL SO $\Delta U = 0$, $Q = W$) |
| 2-3 | + | 0 | (CONST. V HEATING) |
| 3-4 | 0 | + | (ADIABATIC EXPANSION) |
| 4-1 | - | - | (CONST. P COOLING) |

B) LEG 1-2 $q = w$ $w = RT \ln\left(\frac{V_2}{V_1}\right)$
 $T_1 = 300\text{K}$, $p_1 = 100\text{kPa} \Rightarrow V_1 = \frac{RT_1}{p_1} = 0.861 \frac{\text{m}^3}{\text{kg}}$
 $\frac{p_2}{p_1} = 10 \therefore p_2 = 1000\text{kPa}$ $T_2 = 300\text{K}$ (isothermal)
 $\therefore V_2 = \frac{RT_2}{p_2} = 0.0861$

$$\boxed{w = -198 \text{ kJ/kg} \quad q = -198 \text{ kJ/kg}}$$

$$\boxed{\Delta u = C_v \Delta T = 0, \quad \Delta h = C_p \Delta T = 0}$$

LEG 2-3 $w = 0$ (CONST. VOLUME) $\therefore \Delta u = C_v \Delta T = q$
 $T_3 = 1500$ $T_2 = 300 \therefore \Delta u = 716.5(1200) = 859.8 \frac{\text{kJ}}{\text{kg}}$
 $\Delta h = 1003.5(1200) = 1204.2 \frac{\text{kJ}}{\text{kg}}$
 $q = 859.8 \frac{\text{kJ}}{\text{kg}}$

$$T_3 = 1500, V_3 = 0.0861$$

$$\therefore p_3 = \frac{RT_3}{V_3} = 5 \text{ MPa}$$

LEG 3-4 $pV^\gamma = \text{CONST.}$
 $q = 0$ so $w = -C_v(T_4 - T_3)$
 $p_3 V_3^\gamma = p_4 V_4^\gamma$ $p_4 = p_1 = 100\text{kPa}$ $p_3 = 5 \text{ MPa}$
 $V_3 = 0.0861 \therefore V_4 = 1.41 \frac{\text{m}^3}{\text{kg}}$

$$\therefore T_4 = \frac{P_4 V_4}{R} = 491 \text{ K}$$

(2 of 2)

$$\text{SO } q = 0$$

$$W = -76.5 (491 - 1500) = 722.7 \text{ kJ/kg}$$

$$\Delta u = -722.7 \text{ kJ/kg}$$

$$\Delta h = C_p (T_4 - T_3) = -1013 \text{ kJ/kg}$$

LEG 4-1

$$P = \text{CONST. } dh = \cancel{v dp} + v dp \quad C_p (T_1 - T_4) = \Delta h = q$$

$$q = \Delta h = 1003.5 (300 - 491) = -191.7 \text{ kJ/kg}$$

$$\Delta u = C_v (T_1 - T_4) = -137 \text{ kJ/kg}$$

$$\Delta u = q - w$$

$$\therefore w = q - \Delta u = -54.8 \text{ kJ/kg}$$

$$C) W_{\text{cycle}} = W_{1-2} + W_{2-3} + W_{3-4} + W_{4-1}$$

$$= -198 + 0 + 722.7 - 54.8 = 469.9 \text{ kJ/kg}$$

$$D) \eta = \frac{W_{\text{cycle}}}{q_{\text{in}}} = \frac{W_{\text{cycle}}}{859.8 \text{ kJ/kg}} = 0.547$$

$$E) \text{ IN REVERSE, WORK CYCLE} = -469.9 \text{ kJ/kg}$$

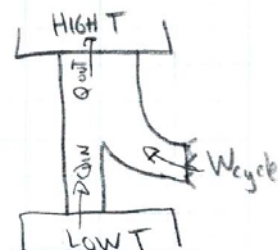
AND ALL SIGNS ON HEAT REVERSED. SO HEAT

FLows INTO SYSTEM (FROM FOOD SAY) ARE

$$\text{DURING LEGS } 2-1 \text{ \& } 1-4 = 198 \text{ kJ/kg} + 191.7 \text{ kJ/kg}$$

$$= 389.7 \text{ kJ/kg}$$

SO 0.83 J COULD BE REMOVED FOR EACH J OF WORK INPUT.



T7 SOLUTIONS (WATZ)

(1 OF 2)

MY DATA WERE OBTAINED 9/16/03 16:50 hrs.

AMBIENT AIR TEMP = 75°F = 297K

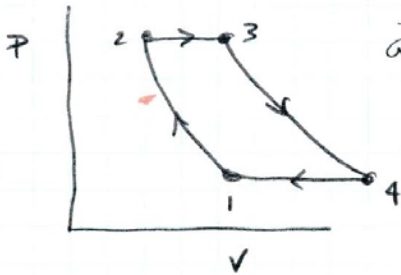
ATMOSPHERIC PRESSURE (ASSUMED) = $1\text{atm} = 101.3\text{ kPa}$

COMPRESSOR DELIVERY PRESSURE = $200\text{ PSIG} = 214.77\text{ PSIA}$

↑
GAGE
(relative to
atmospheric)

↑
ABSOLUTE

SO PRESSURE RATIO = $\frac{214.77}{14.77} = 14.54$



a) ① $P_1 = 101.3\text{ kPa}, T_1 = 297\text{K}$

② $P_2 = 14.54(101.3) = 1473\text{ kPa}$

$\underbrace{\left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}}_{q-s \text{ adiab.}} = \frac{T_2}{T_1} = 2.149 \therefore T_2 = 638\text{K}$

③ constant pressure heating

$\therefore P_3 = 1473\text{ kPa}, T_3 = 1400\text{K (Given)}$

④ q-s adiabatic expansion by $\frac{P_3}{P_4} = 14.54$

$\therefore P_4 = 101.3\text{ kPa}$

$\left(\frac{P_4}{P_3}\right)^{\gamma-1/\gamma} = \frac{T_4}{T_3} = 0.465 \therefore T_4 = 652\text{K}$

b) THERMAL EFFICIENCY

$\eta_{TH} = 1 - \frac{T_1}{T_2} = 1 - \frac{297}{638} = 0.534$

$W = C_p (T_3 - T_2 + T_1 - T_4) = 1003.5 (1400 - 638 + 297 - 652) = 408\text{ kJ/kg}$

c) T_2 FIXED, COLD DAY $T_1 = 273\text{K}$ (2 of 2)

HOT DAY $T_1 = 303\text{K}$

$$\eta_{\text{cold}} = 1 - \frac{273}{638} = 0.57 \quad \eta_{\text{hot}} = 1 - \frac{303}{638} = 0.525$$

d) TOTAL GAS ENERGY FLOW = $66 \times 10^3 \text{ BTU/s} = 69.63 \text{ MJ/s}$
 $= 69.63 \text{ MW}$

ACTIVE LOAD = 20 MW

$$\eta = \frac{20}{69.63} = \frac{W_{\text{cycle}}}{Q_{\text{in}}} = 0.287$$

A VARIETY OF NON-IDEAL PROCESSES CAUSE THE EFFICIENCY TO BE SIGNIFICANTLY LESS THAN THE VALUE OBTAINED FOR THE IDEAL CYCLE.

e) FOR PRESSURE RATIO OF 14.54, CALCULATED $\frac{T_2}{T_1} = 2.149$

SO $T_2 = 638\text{K}$, (IDEAL)

MEASURED T_2 (COMPR DISCHARGE TEMP) = 730°F

* HIGHER THAN
IDEAL γ -S, ADIAB PROCESS

$$T_{2, \text{MEAS.}} = 661\text{K}$$

BUT NOTE THERE IS ALSO SOME COOLING BETWEEN THE AMBIENT ($T_{\text{atm}} = 75^\circ\text{F}$) AND THE COMPRESSOR INLET (COMP INLET TEMP = 62°F) WHICH WAS NOT ACCOUNTED FOR. IF YOU ACCOUNT FOR THIS OUR γ -S, ADIABATIC MODEL IS EVEN WORSE (i.e. SHOWS A SMALLER ΔT THAN IN REAL DEVICE)

T8 SOLUTIONS (WAITZ)1 of 2

a) $P_1 = 1 \times 10^6 \text{ Pa}$, $T_1 = 200 \text{ K}$, $C_1 = 50 \frac{\text{m}}{\text{s}}$ $\dot{m} = 100 \text{ kg/s}$

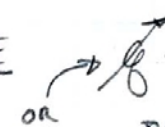
$P_2 = 5 \times 10^6 \text{ Pa}$ via A q -s ADIAB. PROCESS $\therefore P V^\gamma = \text{CONST.}$

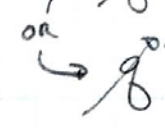
$C_2 = 50 \frac{\text{m}}{\text{s}}$

$\therefore q = 0$

$P_1 V_1 = R T_1 \Rightarrow V_1 = 0.052 \frac{\text{m}^3}{\text{kg}}$ ($R = 260 \text{ J/kg} \cdot \text{K}$)

$P_1 V_1^\gamma = P_2 V_2^\gamma$, $\gamma = \frac{C_p}{C_v} = 1.1 \Rightarrow V_2 = 0.012 \frac{\text{m}^3}{\text{kg}}$

SFEE  $-W_s = h_2 - h_1 + \frac{C_2^2}{2} - \frac{C_1^2}{2}$

or  $-W = u_2 - u_1 + \frac{C_2^2}{2} - \frac{C_1^2}{2}$

$W_f = R(T_2 - T_1) = W - W_s$

so

$W = -\left[C_v(T_2 - T_1) + \frac{C_2^2}{2} - \frac{C_1^2}{2}\right]$, $\frac{P_2 V_2}{R} = T_2 = 230.8 \text{ K}$

$W = -78.2 \frac{\text{kJ}}{\text{kg}}$

or

$\dot{W} = \dot{m} W = -7.8 \text{ MW}$

$W_f = 260(230.8 - 200) = 8 \frac{\text{kJ}}{\text{kg}}$

or

$\dot{W}_f = \dot{m} W_f = 0.8 \text{ MW}$

$W_s = -\left[C_p(T_2 - T_1) + \frac{C_2^2}{2} - \frac{C_1^2}{2}\right] = W - W_f$

$W_s = -86.2 \frac{\text{kJ}}{\text{kg}}$

or $\dot{W}_s = -8.62 \text{ MW}$

b) $C_2 = 50 \text{ m/s}$, $T_2 = 230.8 \text{ K}$, $p_2 = 5 \times 10^6 \text{ Pa}$ 2 of 2
 $C_3 = 100 \text{ m/s}$, $T_3 = ?$, $p_3 = 5 \times 10^6 \text{ Pa}$ $q_{in} = 1300 \text{ kJ/kg}$

$$q - W_s = C_p (T_3 - T_2) + \frac{C_3^2}{2} - \frac{C_2^2}{2} \quad (\text{NO SHAFT WORK BUT CAN STILL BE FLOW WORK})$$

$$1300 \times 10^3 = 2800 (T_3 - 230.8) + \frac{100^2}{2} - \frac{50^2}{2}$$

$$T_3 = 693.7, \quad v_3 = \frac{RT_3}{p_3} = \frac{260 (693.7)}{5 \times 10^6} = 0.036 \frac{\text{m}^3}{\text{kg}}$$

$$W_s = 0 \quad W_f = R (T_3 - T_2)$$

$$W_f = 260 (693.7 - 230.8) = 120 \frac{\text{kJ}}{\text{kg}}$$

or

$$\dot{W}_f = 1.2 \text{ MW}$$

c) $W_{s, \text{TURBINE}} = -W_{s, \text{PUMP}} = 86.2 \frac{\text{kJ}}{\text{kg}}$ or $\dot{W}_s = 8.6 \text{ MW}$

$$-W_s = C_p (T_4 - T_3) + \frac{C_4^2}{2} - \frac{C_3^2}{2}$$

$$-86.2 \times 10^3 = 2800 (T_4 - 693.7) + \frac{120^2}{2} - \frac{100^2}{2}$$

$$T_4 = 662 \text{ K}$$

$$W_f = R (T_4 - T_3) = 260 (662 - 693.7) = -8.2 \frac{\text{kJ}}{\text{kg}}$$

$$W_f = -8.2 \frac{\text{kJ}}{\text{kg}} \quad \text{or} \quad \dot{W}_f = -0.82 \text{ MW}$$

T9 SOLUTIONS (WAITZ)

1 OF 2

a) $p_c = 125 \text{ atm} = p_{Tc}$ ($C_e \approx 0$ IN COMBUSTOR)
 $T_c = 3000 \text{ K} = T_{Tc}$ ($C_e \approx 0$ IN COMBUSTOR)

$$\cancel{0} - \cancel{W_s} = \left(C_p T_e + \frac{C_e^2}{2} \right) - \left(C_p T_c + \frac{C_e^2}{2} \right)$$

$$C_p T_c + \frac{C_e^2}{2} = C_p T_e + \frac{C_e^2}{2} \quad \text{ALSO } \left(\frac{p_e}{p_c} \right)^{\frac{\gamma-1}{\gamma}} = \frac{T_e}{T_c} \quad \text{SINCE}$$

$q-s$ ADIABATIC

$$\Rightarrow C_e = \sqrt{2 C_p T_c \left[1 - \left(\frac{p_e}{p_c} \right)^{\frac{\gamma-1}{\gamma}} \right]}$$

$$= \sqrt{2 (1500) (3000) \left[1 - \left(\frac{1}{125} \right)^{\frac{1.2-1}{1.2}} \right]} \quad \gamma = 1.2$$

$$C_{e_{\text{atm}}} = 2230 \frac{\text{m}}{\text{s}}$$

IN SPACE $\frac{p_e}{p_c} \rightarrow 0$

b)

$$C_{e_{\text{space}}} = 3000 \frac{\text{m}}{\text{s}}$$

$$C_p T_e + \frac{C_e^2}{2} = C_p T_c$$

$$1500(T_e) + \frac{2230^2}{2} = 1500(3000)$$

$$T_{e_{\text{atm}}} = 1342 \text{ K}$$

$$a = \sqrt{\gamma R T_{e_{\text{atm}}}} = 634.5 \text{ m/s}$$

$$M = \frac{C_e}{a} = 3.5$$

b) IN SPACE

$$C_e = 3000 \text{ m/s}$$

$$T_e \rightarrow 0, \quad M_e \rightarrow \infty$$

$$c) \quad \cancel{h_s} - \cancel{h_s} = h_{T_2} - h_{T_c}$$

IF h_{T_c} REDUCED 20% THEN h_{T_2} REDUCED 20%

$$\therefore (C_p T_c)(0.8) = C_p T_2 + \frac{C_a^2}{2}$$

$$\therefore C_a = \sqrt{2 C_p T_c (0.8) \left[1 - \left(\frac{P_2}{P_c} \right)^{\frac{\gamma-1}{\gamma}} \right]}$$

$$C_{a_{atm}} = \sqrt{2 (1500) (3000) (0.8) \left[1 - \left(\frac{1}{125} \right)^{\frac{1.2-1}{1.2}} \right]}$$

$$\boxed{C_{a_{atm}} = 1995 \text{ m/s}}$$

$$C_{a_{space}} \Rightarrow P_2/P_c \rightarrow 0$$

$$C_{a_{space}} = \sqrt{2 (1500) (3000) (0.8) [1]}$$

$$\boxed{C_{a_{space}} = 2683 \text{ m/s}}$$