Shri Vile Parle Kelavani Mandal's
**DWARKADAS J. SANGHVI COLLEGE OF ENGINEERING**
(Autonomous College Affiliated to the University of Mumbai)
NAAC Accredited with "A" Grade (CGPA : 3.18)

# POA LAB EXPERIMENTS

| | |
|---|---|
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| **Division** | A |
| **Batch** | A4 |
| **Branch** | Computer Engineering |
| **Semester** | 5 |
| **Subject** | Processor Organization and Architecture |
| **Subject Code** | DJ19CEL502 |

## Experiment List

# EXPERIMENT - 1

**AIM:** To demonstrate Booth's Algorithm for multiplication of 2 signed binary numbers.

**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 01-10-2021 | 01-10-2021 | |

**THEORY**:

Booth algorithm gives a procedure for multiplying binary integers in signed 2's complement representation in an efficient way, i.e., less number of additions/subtractions required. It operates on the fact that strings of 0's in the multiplier require no addition but just shifting and a string of 1's in the multiplier from bit weight 2^k to weight 2^m can be treated as 2^(k+1 ) to 2^m.

Booth's algorithm can be implemented by repeatedly adding (with ordinary unsigned binary addition) one of two predetermined values *A* and *S* to a product *P*, then performing a rightward arithmetic shift on *P*. Let **m** and **r** be the multiplicand and multiplier, respectively; and let *x* and *y* represent the number of bits in **m** and **r**.

1. Determine the values of *A* and *S*, and the initial value of *P*. All of these numbers should have a length equal to ($x + y + 1$).
    1. A: Fill the most significant (leftmost) bits with the value of **m**. Fill the remaining ($y + 1$) bits with zeros.
    2. S: Fill the most significant bits with the value of (−**m**) in two's complement notation. Fill the remaining ($y + 1$) bits with zeros.
    3. P: Fill the most significant *x* bits with zeros. To the right of this, append the value of **r**. Fill the least significant (rightmost) bit with a zero.
2. Determine the two least significant (rightmost) bits of *P*.
    1. If they are 01, find the value of $P + A$. Ignore any overflow.
    2. If they are 10, find the value of $P + S$. Ignore any overflow.
    3. If they are 00, do nothing. Use *P* directly in the next step.
    4. If they are 11, do nothing. Use *P* directly in the next step.

3. Arithmetically shift the value obtained in the 2nd step by a single place to the right. Let *P* now equal this new value.
4. Repeat steps 2 and 3 until they have been done *y* times.
5. Drop the least significant (rightmost) bit from *P*. This is the product of **m** and **r**.

TIME COMPLEXITY: O(n) * (complexity_of_addition + complexity_of_shift)

**EXAMPLE**: Multiplication of 7 and 3

| $Q_n$ | $Q_{n+1}$ | M = (0111)<br>M' + 1 = (1001) & Operation | AC | Q | $Q_{n+1}$ | SC |
|---|---|---|---|---|---|---|
| 1 | 0 | Initial | 0000 | 0011 | 0 | 4 |
| | | **Subtract** (M' + 1) | 1001 | | | |
| | | | 1001 | | | |
| | | Perform Arithmetic Right Shift operations (ashr) | 1100 | 1001 | 1 | 3 |
| 1 | 1 | Perform Arithmetic Right Shift operations (ashr) | 1110 | 0100 | 1 | 2 |
| **0** | **1** | Addition (A + M) | 0111 | | | |
| | | | 0101 | 0100 | | |
| | | Perform Arithmetic right shift operation | 0010 | 1010 | 0 | 1 |
| 0 | 0 | Perform Arithmetic right shift operation | **0001** | **0101** | 0 | 0 |

**Final Answer** = $(0001\ 0101)_2$
= $(21)_{10}$

**CODE**:

```
#include<stdio.h>
#include<stdlib.h>
#include<string.h>

void rightShift();

int main()
```

```
{
   printf("\n");
   printf("BOOTH's Algorithm\n");
   printf("\n");
   printf("Enter two numbers that are to be multiplied : ");//taking two numbers as inputs
   int a,b;
   scanf("%d %d",&a,&b);
   int ap=a,bp=b;
   if(ap<0) // Negetive values check
      ap*=-1;
   if(bp<0) bp*=-1;
   if(bp>ap) //taking greater VALUE as multiplicand
   {
      ap=bp+ap-(bp=ap);
      a=b+a-(b=a);
   }
   int t1=ap,t2=bp;
   int ab[35]={};
   int bb[35]={};
   int i=0;
   while(t1>0)
   {
      ab[i]=t1%2;
      i++;
      t1/=2;
   }
   ab[i]=0;
   int j=0;
   while(t2>0)
   {
      bb[j]=t2%2;
      j++;
      t2/=2;
   }
   while(j<=i) //equating bits to the previous(ab) binary number(ab will either be larger or equal to
bb).
      bb[j++]=0;
   int nb=i+1; //nb is number of bits
   i=0;j=0;
   while(i<nb/2) //converting VALUES to binary
   {
      ab[i]=ab[nb-i-1]+ab[i]-(ab[nb-i-1]=ab[i]);
      i++;
   }
   i=0;
   while(i<nb/2) { bb[i]=bb[nb-i-1]+bb[i]-(bb[nb-i-1]=bb[i]); i++; } int x[35]={0}; int y[35]={0}; i=0; if(a>=0)
//taking actual binary numbers
```

```
  { //x is multiplicand and y is multiplier
    while(i<nb)
    x[i]=ab[i+++1];
  }
  else //2's complimant
  {
    while(i<nb) { if(ab[i]==0) x[i]=1; else x[i]=0; i++; } i=1; x[nb-i]++; while(x[nb-i]==2) { x[nb-i]=0; i++;
x[nb-i]++; } } i=0; if(b>=0)
  {
    while(i<nb)
      y[i]=bb[i+++1];
  }
  else //2's complimant
  {
    while(i<nb) { if(bb[i]==0) y[i]=1; else y[i]=0; i++; } i=1; y[nb-i]++; while(y[nb-i]==2) { y[nb-i]=0; i++;
y[nb-i]++; } } printf("\n"); //output starts here printf("Multiplicand (Q) %d -> ",a);
  i=0;
  printf("Multiplicand (Q) -> ");
  while(i<nb) printf("%d",x[i++]); printf("\nMultiplier (M) %d -> ",b);
  i=0;
  while(i<nb)
    printf("%d",y[i++]);
  printf("\n");
  i=0;
  int ym[35]={0}; //calculating -M
  if(b<0)
  {
    while(i<nb)
    ym[i]=bb[i+++1];
  }
  else
  {
    while(i<nb) { if(bb[i]==0) ym[i]=1; else ym[i]=0; i++; } i=1; ym[nb-i]++; while(ym[nb-i]==2) {
ym[nb-i]=0; i++; ym[nb-i]++; } } printf("we use -(M) i.e. %d -> ",-b);
  i=0;
  while(i<nb)
    printf("%d",ym[i++]);
  printf("\n");
  int q0=0;
  int p[35]={0}; //p here is value that is stored in accumulator. initially set to zero.
  int steps=nb;
  printf("\n");
  printf("n\t");
  i=0;
  while(i<nb)
  {
    if(i*2==nb || i*2==nb-1)
```

```
        printf("A");
        else
        printf(" ");
        i++;
    }
    printf(" ");
    i=0;
    while(i<nb)
    {
        if(i*2==nb || i*2==nb-1)
            printf("Q\t");
        else
            printf(" ");
        i++;
    }
    printf(" Q-1");
    printf("\n");
    j=0;

    while(steps--) //counting down steps.
    {
        printf("%d        ",j++);
        i=0;
        while(i<nb)
            printf("%d",p[i++]);
        printf(" ");
        i=0;
        while(i<nb)
            printf("%d",x[i++]);
        printf(" ");
        printf("%d\n",q0);
        if(x[nb-1]==0 && q0==0) //0-0 condition
        {
            q0=x[nb-1];
            rightShift(p,x,nb);
        }
        else if(x[nb-1]==0 && q0==1) //0-1 condition
        {
            printf("    A + M ");
            i=0;
            while(i<nb)
                printf("%d",y[i++]);
            i=0;
            while(i<nb)
            {
                p[nb-i-1]+=y[nb-i-1];
                if(p[nb-i-1]==2)
```

```
            {
              p[nb-i-1]=0;
              if(nb-i-1!=0)
              p[nb-i-2]++;
            }
            if(p[nb-i-1]==3)
            {
              p[nb-i-1]=1;
              if(nb-i-1!=0)
              p[nb-i-2]++;
            }
            i++;
          }
          printf("\n          ");
          i=0;
          while(i<nb)
            printf("%d",p[i++]);
          printf("\n");
          q0=x[nb-1];
          rightShift(p,x,nb);
        }
        else if(x[nb-1]==1 && q0==0) //1-0 condition
        {
          printf("    A - M ");
          i=0;
          while(i<nb)
            printf("%d",ym[i++]);
          i=0;
          while(i<nb)
          {
            p[nb-i-1]+=ym[nb-i-1];
            if(p[nb-i-1]==2)
            {
              p[nb-i-1]=0;
              if(nb-i-1!=0)
              p[nb-i-2]++;
            }
            if(p[nb-i-1]==3)
            {
              p[nb-i-1]=1;
              if(nb-i-1!=0)
              p[nb-i-2]++;
            }
            i++;
          }
          printf("\n          ");
          i=0;
```

```
        while(i<nb)
          printf("%d",p[i++]);
        printf("\n");
        q0=x[nb-1];
        rightShift(p,x,nb);
      }
      else if(x[nb-1]==1 && q0==1) //1-1 condition
      {
        q0=x[nb-1];
        rightShift(p,x,nb);
      }
    }
    printf("%d        ",j);
    i=0;
    while(i<nb)
      printf("%d",p[i++]);
    printf(" ");
    i=0;
    while(i<nb)
      printf("%d",x[i++]);
    printf(" ");
    printf("%d\n",q0);
    printf("\n");

    printf("Final Product in signed binary number is : ");
    i=0;
    while(i<nb)
      printf("%d",p[i++]);
    i=0;
    printf(" ");
    while(i<nb)
      printf("%d",x[i++]);
    printf("\n\n");
    return 0;
}

void rightShift(int p[],int x[],int nb)
{
    int i=0;
    while(nb-i-1)
    {
      x[nb-i-1]=x[nb-i-2];
      i++;
    }
    x[0]=p[nb-1];
    i=0;
    while(nb-i-1)
```

```
    {
      p[nb-i-1]=p[nb-i-2];
      i++;
    }
}
```

## OUTPUT:

```
BOOTH's Algorithm

Enter two numbers that are to be multiplied : 20 35

Multiplicand (Q) -> 0100011
Multiplier (M) 20 -> 0010100
we use -(M) i.e. -20 -> 1101100

n          A       Q        Q-1
0          0000000 0100011 0
    A - M 1101100
          1101100
1          1110110 0010001 1
2          1111011 0001000 1
    A + M 0010100
          0001111
3          0000111 1000100 0
4          0000011 1100010 0
5          0000001 1110001 0
    A - M 1101100
          1101101
6          1110110 1111000 1
    A + M 0010100
          0001010
7          0000101 0111100 0

Final Product in signed binary number is : 0000101 0111100


...Program finished with exit code 0
Press ENTER to exit console.
```

# EXPERIMENT - 2

**AIM:** To demonstrate the Restoring Division Algorithm for 2 unsigned binary numbers.

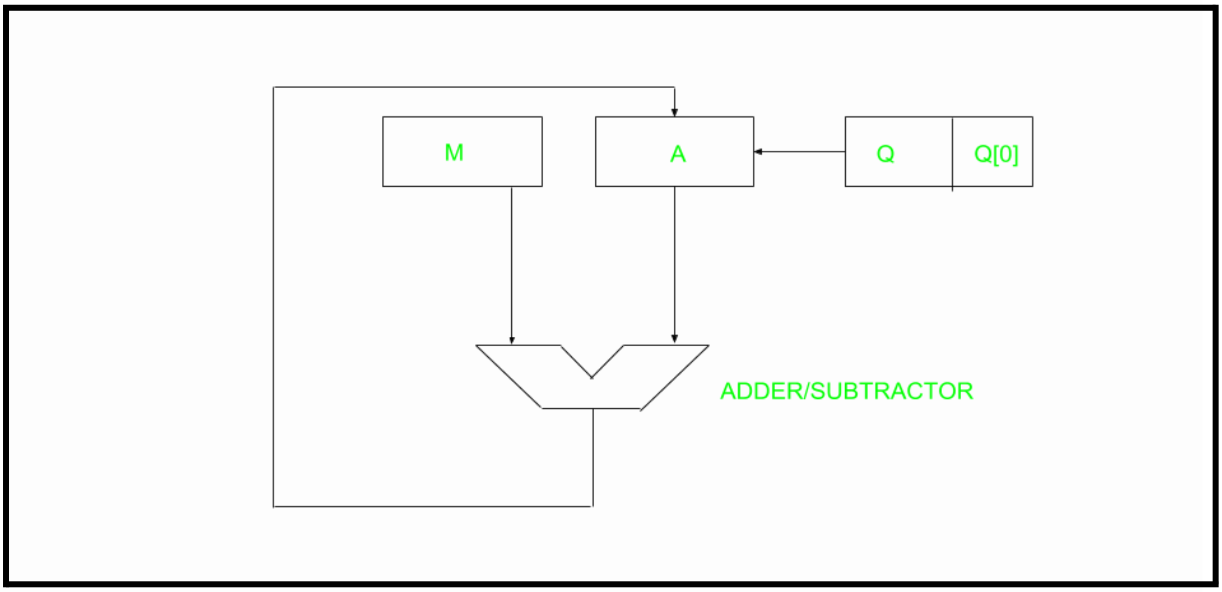
**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 08-10-2021 | 08-10-2021 | |

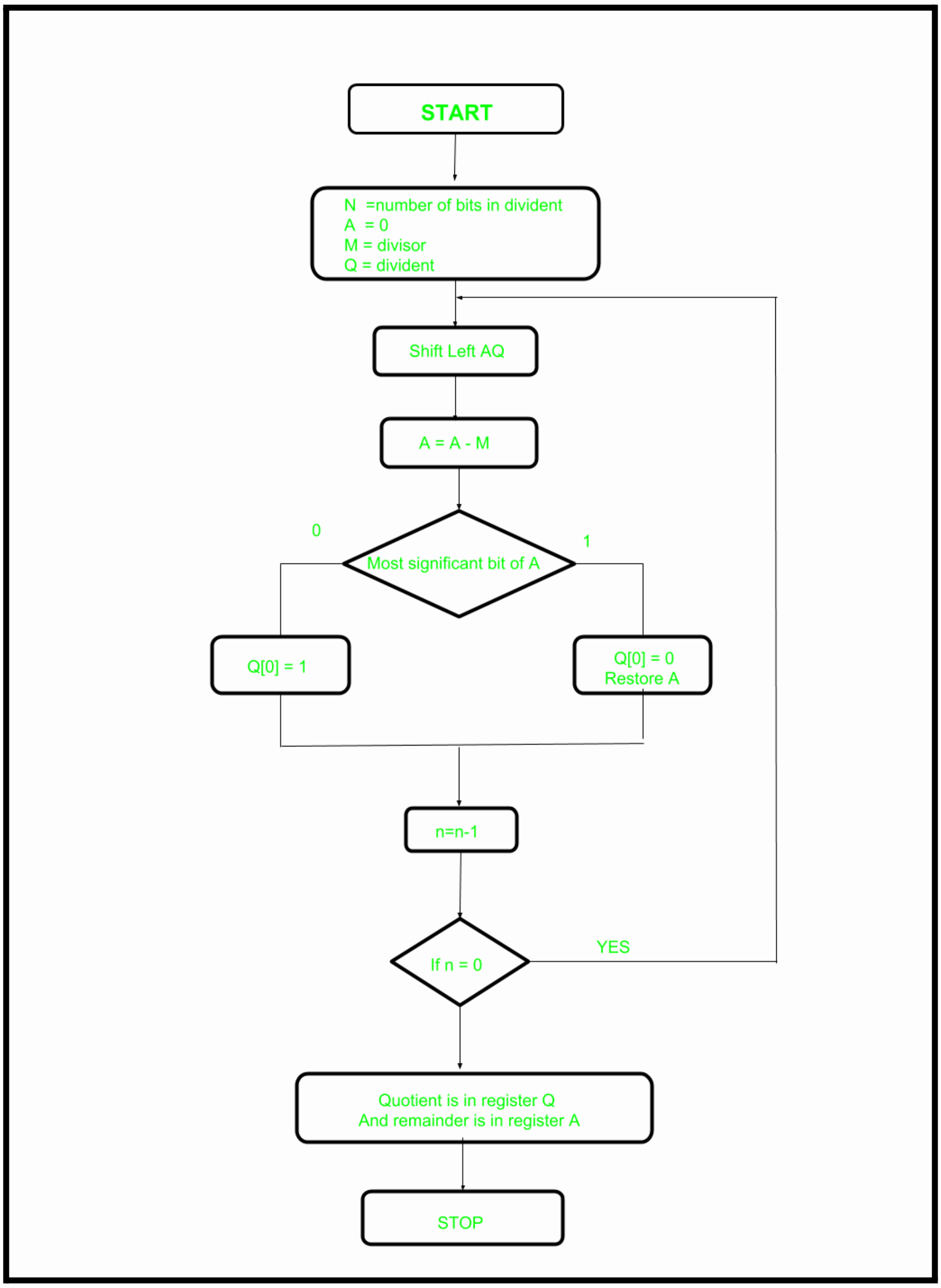
**THEORY:**

A division algorithm provides a quotient and a remainder when we divide two number. They are generally of two type **slow algorithm and fast algorithm**. Slow division algorithm are restoring, non-restoring, non-performing restoring, SRT algorithm and under fast comes Newton–Raphson and Goldschmidt.

In this article, will be performing restoring algorithm for unsigned integer. Restoring term is due to fact that value of register A is restored after each iteration.



Here, register Q contain quotient and register A contain remainder. Here, n-bit dividend is loaded in Q and divisor is loaded in M. Value of Register is initially kept 0 and this is the register whose value is restored during iteration due to which it is named Restoring.



Let’s pick the step involved:

- **Step-1:** First the registers are initialized with corresponding values (Q = Dividend, M = Divisor, A = 0, n = number of bits in dividend)
- **Step-2:** Then the content of register A and Q is shifted right as if they are a single unit
- **Step-3:** Then content of register M is subtracted from A and result is stored in A
- **Step-4:** Then the most significant bit of the A is checked if it is 0 the least significant bit of Q is set to 1 otherwise if it is 1 the least significant bit of Q is set to 0 and value of register A is restored i.e the value of A before the subtraction with M
- **Step-5:** The value of counter n is decremented
- **Step-6:** If the value of n becomes zero we get of the loop otherwise we repeat fro step 2
- **Step-7:** Finally, the register Q contain the quotient and A contain remainder

**Examples:**

Perform Division Restoring Algorithm
Dividend = 11

Divisor = 3

| n | M | A | Q | Operation |
|---|---|---|---|---|
| 4 | 00011 | 00000 | 1011 | initialize |
| | 00011 | 00001 | 011_ | shift left AQ |
| | 00011 | 11110 | 011_ | A=A-M |
| | 00011 | 00001 | 0110 | Q[0]=0 And restore A |
| 3 | 00011 | 00010 | 110_ | shift left AQ |
| | 00011 | 11111 | 110_ | A=A-M |
| | 00011 | 00010 | 1100 | Q[0]=0 |
| 2 | 00011 | 00101 | 100_ | shift left AQ |
| | 00011 | 00010 | 100_ | A=A-M |
| | 00011 | 00010 | 1001 | Q[0]=1 |
| 1 | 00011 | 00101 | 001_ | shift left AQ |
| | 00011 | 00010 | 001_ | A=A-M |
| | 00011 | 00010 | 0011 | Q[0]=1 |

Remember to restore the value of A, most significant bit of A is 1. As that register Q contains the quotient, i.e. 3 and register A contains remainder 2.

CODE:

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
```

```
int getsize(int x)
{
int c;
if(x<=1)
c = 2;
else if(x < 4)
c = 2;
else if(x< 8)
c = 3;
else if(x< 16)
c = 4;
else if(x< 32)
c = 5;
else if(x< 64)
c = 6;
else if(x< 128)
c = 7;
else if(x< 256)
c = 8;
else if(x< 512)
c = 9;
return c;
}

int max(int x,int y)
{
if(x< y)
return(y);
else
return(x);
}

void main()
{
int B,Q,Z,M,c,c1,e,f,g,h,i,j,x,y,ch,in,S,G,P;
int a[24],b[12],b1[12],q[12],carry=0,count=0,option;
long num;

printf("¦\t\tPROGRAM FOR RESTORING DIVISION\t\t¦\n");
```

```
printf("\n\nENTER DIVIDEND\t: ");
scanf("%d",&Q);
y = getsize(Q);
printf("ENTER DIVISOR\t: ");
scanf("%d",&M);
x = getsize(M);
Z = max(x,y);
printf("\n\tTOTAL BITS CONSIDERED FOR RESULT => %d",2*Z+1);
printf("\n\tINITiALLY A IS RESET TO ZERO:");
for(i=0;i<=Z;i++)
printf("%d ",a[i]=0);
for(i=Z;i>=0;i--)
{
b1[i] = b[i] = M%2;
M = M/2;
b1[i] = 1-b1[i];
}
carry = 1;
for(i=Z;i>=0;i--)
{
c1 = b1[i]^carry;
carry = b1[i]&&carry;
b1[i]=c1;
}
for(i=2*Z;i>Z;i--)
{
a[i] = Q%2;
Q = Q/2;
}
printf("\n\n\tDivisor\t\t(M)\t: ");
for(i=0;i<=Z;i++)
printf("%d ",b[i]);
printf("\n\t2'C Divisor\t(-M)\t: ");
for(i=0;i<=Z;i++)
printf("%d ",b1[i]);
printf("\n\tDividend\t(Q)\t: ");
for(i=Z+1;i<=2*Z;i++)
printf("%d ",a[i]);
printf("\n\n\tBITS CONSIDERED:[ A ]\t[ M ]");
```

```
printf("\n\t\t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
printf(" ");
for(i=Z+1;i<=2*Z;i++)
printf("%d ",a[i]);
count = Z;
do{
for(i=0;i<2*Z;i++)
a[i] = a[i+1];
printf("\n\nLeft Shift\t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
printf(" ");
for(i=Z+1;i< 2*Z;i++)
printf("%d ",a[i]);
carry=0;
for(i=Z;i>=0;i–)
{
S=a[i]^(b1[i]^carry);
G=a[i]&&b1[i];
P=a[i]^b1[i];
carry=G||(P&&carry);
a[i]=S ;
}
printf("\nA< -A-M \t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
printf(" ");
for(i=Z+1;i< 2*Z;i++)
printf("%d ",a[i]);
ch=a[0];
printf("\nBIT Q:%d",ch);
switch (ch)
{
case 0: a[2*Z]=1;
printf(" Q0< -1\t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
```

```
printf(" ");
for(i=Z+1;i<=2*Z;i++)
printf("%d ",a[i]);
break;

case 1: a[2*Z]=0;
printf(" Q0< -0\t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
printf(" ");
for(i=Z+1;i< 2*Z;i++)
printf("%d ",a[i]);
carry=0;
for(i=Z;i>=0;i–)
{
S=a[i]^(b[i]^carry);
G=a[i]&&b[i];
P=a[i]^b[i];
carry=G||(P&&carry);
a[i]=S ;
}
printf("\nA< -A+M");
printf("\t\t\t");
for(i=0;i<=Z;i++)
printf("%d ",a[i]);
printf(" ");
for(i=Z+1;i<=2*Z;i++)
printf("%d ",a[i]);
break;
}
count–;
}while(count!=0);
num=0;
printf("\n\n\t\tQUOTIENT IN BITS :");
for(i=Z+1;i<=2*Z;i++)
{
printf("%d ",a[i]);
num=num+pow(2,2*Z-i)*a[i];
}
```

```
printf("\n\t\tOUOTIENT IN DECIMAL :%ld",num);
num=0;
printf("\n\t\tREMAINDER IN BITS :");
for(i=0;i<=Z;i++)
{
printf("%d ",a[i]);
num=num+pow(2,Z-i)*a[i];
}
printf("\n\t\tREMAINDER IN DECIMAL :%ld",num);
getch();

getch();
}
```

OUTPUT:

```
¦                PROGRAM FOR RESTORING DIVISION                ¦


ENTER DIVIDEND   : 17
ENTER DIVISOR    : 4

        TOTAL BITS CONSIDERED FOR RESULT => 11
        INITiALLY A IS RESET TO ZERO:0 0 0 0 0 0

        Divisor          (M)      : 0 0 0 1 0 0
        2'C Divisor      (-M)     : 1 1 1 1 0 0
        Dividend         (Q)      : 1 0 0 0 1

        BITS CONSIDERED:[ A ]     [ M ]
                        0 0 0 0 0 0  1 0 0 0 1

Left Shift              0 0 0 0 0 1  0 0 0 1
A< -A-M                 1 1 1 1 0 1  0 0 0 1
BIT Q:1 Q0< -0          1 1 1 1 0 1  0 0 0 1
A< -A+M                 0 0 0 0 0 1  0 0 0 1 0

Left Shift              0 0 0 0 1 0  0 0 1 0
A< -A-M                 1 1 1 1 1 0  0 0 1 0
BIT Q:1 Q0< -0          1 1 1 1 1 0  0 0 1 0
A< -A+M                 0 0 0 0 1 0  0 0 1 0 0

Left Shift              0 0 0 1 0 0  0 1 0 0
A< -A-M                 0 0 0 0 0 0  0 1 0 0
BIT Q:0 Q0< -1          0 0 0 0 0 0  0 1 0 0 1

Left Shift              0 0 0 0 0 0  1 0 0 1
A< -A-M                 1 1 1 1 0 0  1 0 0 1
BIT Q:1 Q0< -0          1 1 1 1 0 0  1 0 0 1
A< -A+M                 0 0 0 0 0 0  1 0 0 1 0

Left Shift              0 0 0 0 0 1  0 0 1 0
A< -A-M                 1 1 1 1 0 1  0 0 1 0
BIT Q:1 Q0< -0          1 1 1 1 0 1  0 0 1 0
A< -A+M                 0 0 0 0 0 1  0 0 1 0 0

                QUOTIENT IN BITS :0 0 1 0 0
                QUOTIENT IN DECIMAL :4
                REMAINDER IN BITS :0 0 0 0 0 1
                REMAINDER IN DECIMAL :1
```

**CONCLUSION**: From this experiment, we learn how to use the restoring division algorithm to divide unsigned bits. We understood that it is a type of slow algorithm along with non-restoring division. We also learn how to write the code for the same algorithm in C language and implement it successfully.

# EXPERIMENT - 3

**Aim:** To study and implement non-restoring division algorithms.

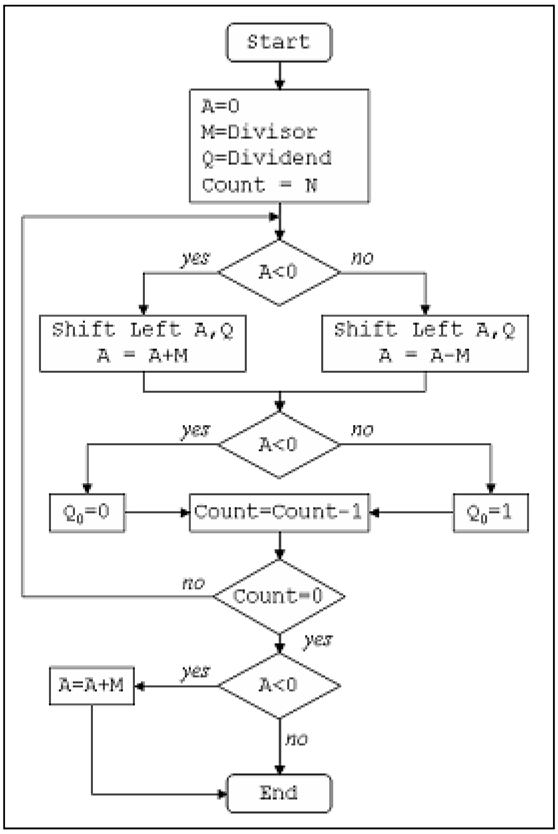
**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 30-10-2021 | 30-10-2021 | |

## Theory

A division algorithm is an algorithm which, given two integers N and D, computes their quotient and/or remainder, the result of Euclidean division. Division algorithms fall into two main categories: slow division and fast division. Slow division algorithms produce one digit of the final quotient per iteration. Examples of slow division include restoring, non-performing restoring, non-restoring, and SRT division. Fast division methods start with a close approximation to the final quotient and produce twice as many digits of the final quotient on each iteration. Newton–Raphson and Goldschmidt algorithms fall into this category.

Non-Restoring division, it is less complex than the restoring one because simpler operations are involved i.e. addition and subtraction, also now the restoring step is performed. In the method, rely on the sign bit of the register which initially contains zero named as A.
Here is the flow chart given below.




Algorithm

```
1) Set the value of register A as 0 (N bits)
2) Set the value of register M as Divisor (N bits)
3) Set the value of register Q as Dividend (N bits)
4) Concatenate A with Q {A,Q}
5) Repeat the following "N" number of times (here N is no. of bits in divisor):
    If the sign bit of A equals 0,
      shift A and Q combined left by 1 bit and subtract M from A,
    else shift A and Q combined left by 1 bit and add M to A
    Now if sign bit of A equals 0, then set Q[0] as 1, else set Q[0] as 0
6) Finally if the sign bit of A equals 1 then add M to A.
7) Assign A as remainder and Q as quotient.
```

## Example:

Dividend (A) = 101110, ie 46, and Divisor (B) = 010111, ie 23.

Initialization :
Set Register A = Dividend = 000000
Set Register Q = Dividend = 101110
( So AQ = 000000 101110 , Q0 = LSB of Q = 0 )
Set M = Divisor = 010111, M' = 2's complement of M = 101001
Set Count = 6, since 6 digits operation is being done here.

After this we start the algorithm, which I have shown in a table below :
In the table, SHL(AQ) denotes shift left AQ by one position leaving Q0 blank.
Similarly, a square symbol in Q0 position denote, it is to be calculated later

| Action | A | Q | Count |
|---|---|---|---|
| Initial | 000 000 | 101 110 | 6 |
| | | | |
| A > 0 => SHL (AQ) | 000 001 | 011 10□ | |
| A = A-M | 101 010 | 011 10□ | |
| A < 0 => Q0 = 0 | 101 010 | 011 100 | 5 |
| | | | |
| A < 0 => SHL (AQ) | 010 100 | 111 00□ | |
| A = A+M | 101 011 | 111 00□ | |
| A < 0 => Q0 = 0 | 101 011 | 111 000 | 4 |
| | | | |
| A < 0 => SHL (AQ) | 010 111 | 110 00□ | |
| A = A+M | 101 110 | 110 00□ | |
| A < 0 => Q0 = 0 | 101 110 | 110 000 | 3 |
| | | | |
| A < 0 => SHL (AQ) | 011 101 | 100 00□ | |
| A = A+M | 110 100 | 100 00□ | |
| A < 0 => Q0 = 0 | 110 100 | 100 000 | 2 |
| | | | |
| A < 0 => SHL (AQ) | 101 001 | 000 00□ | |
| A = A+M | 000 000 | 000 00□ | |
| A < 0 => Q0 = 1 | 000 000 | 000 001 | 1 |
| | | | |
| A > 0 => SHL (AQ) | 000 000 | 000 01□ | |
| A = A+M | 101 001 | 000 01□ | |
| A < 0 => Q0 = 1 | 101 001 | 000 010 | 0 |
| | | | |
| **Count has reached Zero, So final steps** | | | |
| | | | |
| A < 0 => A = A+M | **000 000** | **000 010** | |
| | **Reminder** | **Quotient** | |

CODE:

```
#include<stdio.h>
#include<malloc.h>
int *a,*q,*m,*mc,*c,n,d;
int powr(int x,int y)
{
 int s=1,i;
 for(i=0;i<y;i++)
   s=s*x;
 return s;
}
void print(int arr[],int n)
{
 int i;
 for(i=0;i<n;i++)
  printf("%d ",arr[i]);
}
void bin(int n, int arr[]){
    int r, i = 0;
    do{
        r = n % 2;
        n /= 2;
        arr[i] = r;
        i++;
    }while(n > 0);
 }
void set(int array[], int x){
    int i,tmp[20]={0};
    for(i = x -1; i >=0; i--)
  tmp[x-1-i]=array[i];
 for(i=0;i<x;i++)
  array[i]=tmp[i];
 }
int len(int x)
{
 int i=0;
 while(powr(2,i)<=x) i++;
 return ++i;
}
```

```
void addBinary(int a1[], int a2[])
{
    int bi[2]={0},ca[20]={0};
    int t=len(n),tmp=0;
    int *su=(int*)malloc(sizeof(int)*len(n));
 while(t-->0)
 {
  tmp=a1[t]+a2[t]+ca[t];
  bin(tmp,bi);
  su[t]=bi[0];
  ca[t-1]=bi[1];
  bi[0]=0;bi[1]=0;
 }
 for(t=0;t<len(n);t++)
  a1[t]=su[t];
 free(su);
 }

void twoCom(int arr[]){
    int i;
    int *one=(int*)malloc(sizeof(int)*len(n));
    for(i=0;i<len(n)-1;i++)
  one[i]=0;
 one[i]=1;
    for(i = 0; i < len(n); i++){
        arr[i]=1-arr[i];
    }
    addBinary(arr, one);
    free(one);
}
void ls(int alen,int blen)
{
 int i=0;
 for(i=0;i<alen-1;i++)
  a[i]=a[i+1];
 a[i]=q[0];
 for(i=0;i<blen-1;i++)
  q[i]=q[i+1];
 q[i]=-1;
}
```

```
void printaq()
{
 print(a,len(n));
 printf("\t");
 print(q,len(n)-1);
 printf("\t");
 printf("\n");
}
int main()
{
 int i,cnt=0;
 printf("Enter The Numerator/Denominator: ");
 scanf("%d/%d",&n,&d);
 q=(int*)malloc(sizeof(int)*len(n)-1);
 bin (n,q);
 m=(int*)malloc(sizeof(int)*(len(n)));
 bin(d,m);
 a=(int*)malloc(sizeof(int)*(len(n)));
 for(i=0;i<len(n);i++)
  a[i]=0;
 mc=(int*)malloc(sizeof(int)*(len(n)));
 bin(d,mc);
 set(q,len(n)-1);
 set(m,len(n));
 set(mc,len(n));
 twoCom(mc);
 cnt=len(n)-1;
 printf("\t    A\t\t   Q\t\t    M\t    Count\n");
 printf("\t---------\t-------\t\t--------- ---------\n");
 while(cnt>0)
 {
  printf("\t");
  print(a,len(n));
  printf("\t");
  print(q,len(n)-1);
  printf("\t");
  print(m,len(n));
  printf("\t%d\n",cnt);
  if(a[0]==1)
  {
```

```
    ls(len(n),len(n)-1);
    printf("LSHIFT\t");
    printaq();
    addBinary(a,m);
    printf("A=A+M\t");
    printaq();
   }
   else
   {
    ls(len(n),len(n)-1);
    printf("LSHIFT\t");
    printaq();
    addBinary(a,mc);
    printf("A=A-M\t");
    printaq();
   }
   if(a[0]==1)
   {
    q[len(n)-2]=0;
    addBinary(a,m);
   }
   else
    q[len(n)-2]=1;
   printf("A=A+M\t");
   printaq();
   cnt-=1;
   printf("\n");
  }
 return 0;
}
```

OUTPUT:

```
Enter The Numerator/Denominator: 10/3
                A                   Q                   M          Count
         ----------          -------             ----------  ----------
          0 0 0 0 0           1 0 1 0             0 0 0 1 1           4
LSHIFT    0 0 0 0 1           0 1 0 -1
A=A-M     1 1 1 1 0           0 1 0 -1
A=A+M     0 0 0 0 1           0 1 0 0

          0 0 0 0 1           0 1 0 0             0 0 0 1 1           3
LSHIFT    0 0 0 1 0           1 0 0 -1
A=A-M     1 1 1 1 1           1 0 0 -1
A=A+M     0 0 0 1 0           1 0 0 0

          0 0 0 1 0           1 0 0 0             0 0 0 1 1           2
LSHIFT    0 0 1 0 1           0 0 0 -1
A=A-M     0 0 0 1 0           0 0 0 -1
A=A+M     0 0 0 1 0           0 0 0 1

          0 0 0 1 0           0 0 0 1             0 0 0 1 1           1
LSHIFT    0 0 1 0 0           0 0 1 -1
A=A-M     0 0 0 0 1           0 0 1 -1
A=A+M     0 0 0 0 1           0 0 1 1
```

## Conclusion :

The non-restorative division algorithm is an efficient way to perform binary division compared to traditional subtractive based algorithms by using the faster processed bit shift commands in the CPU registers. The algorithm is simple enough to be implemented in hardware in equipment like Arithmometers while also generalising to complex modern day systems. The algorithm serves as a good example in showing that considering lower-level system dependencies and physical limitations can be used to optimize algorithms. Non-restorative algorithm is more efficient than restorative algorithm as it uses simpler commands in terms of addition and subtraction, however it is slower than other algorithms.

# EXPERIMENT - 4

**Aim:**

Implement Sequential memory organization with following details:

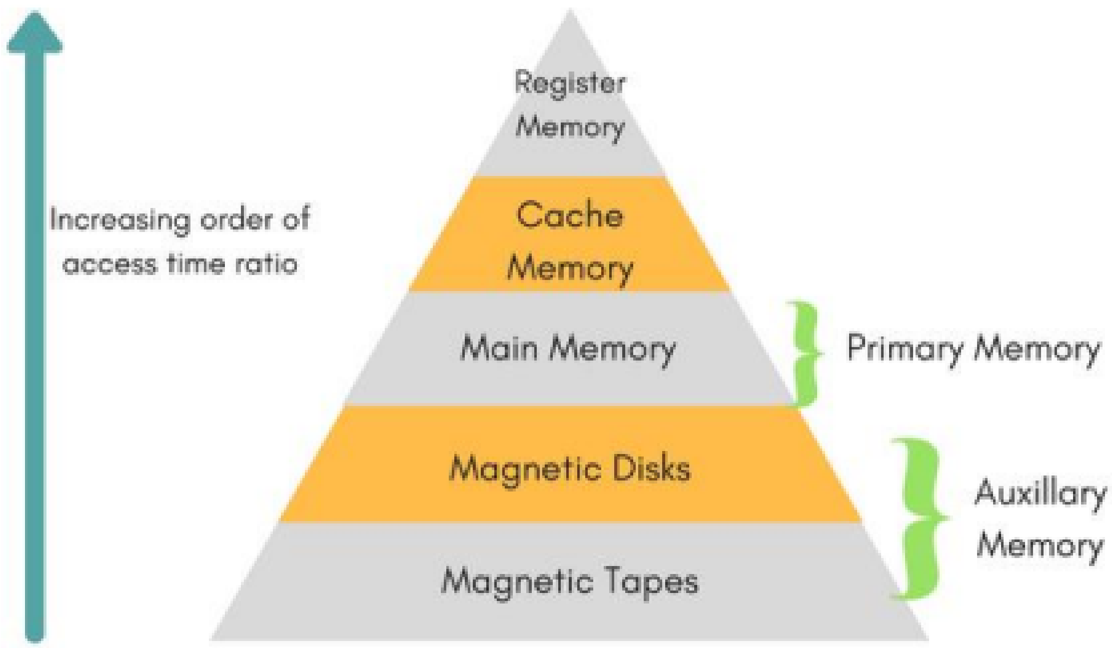
- Processor can access 1 word = 4 bytes.
- L1 cache can store max = 32 words.
- L2 cache can store max =128 words.
- Main memory can store max = 2048 bytes.

**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 30-10-2021 | 30-10-2021 | |

**Theory:**

In Computer System Design, Memory Hierarchy is an enhancement to organize the memory such that it can minimize the access time. The Memory Hierarchy was developed based on a program behaviour known as locality of references. The figure below clearly demonstrates the different levels of memory hierarchy:




This Memory Hierarchy Design is divided into 2 main types:

- External Memory or Secondary Memory – Comprising of Magnetic Disk, Optical Disk, Magnetic Tape i.e., peripheral storage devices which are accessible by the processor via I/O Module.
- Internal Memory or Primary Memory – Comprising of Main Memory, Cache Memory & CPU registers. This is directly accessible by the processor.

<u>Levels of memory:</u>

- Level 1 or Register –

  It is a type of memory in which data is stored and accepted that are immediately stored in CPU. Most commonly used register is accumulator, Program counter, address register etc.

- Level 2 or Cache memory –

  It is the fastest memory which has faster access time where data is temporarily stored for faster access.

- Level 3 or Main Memory –

  It is memory on which computer works currently. It is small in size and once power is off data no longer stays in this memory.

- Level 4 or Secondary Memory –

  It is external memory which is not as fast as main memory but data stays permanently in this memory.

Types of Cache:

- Primary Cache –

  A primary cache is always located on the processor chip. This cache is small and its access time is comparable to that of processor registers.

- Secondary Cache –

  Secondary cache is placed between the primary cache and the rest of the memory. It is referred to as the level 2 (L2) cache. Often, the Level 2 cache is also housed on the processor chip.

**Code:**

```
memory.cpp
#include<bits/stdc++.h>
#include<time.h>
using namespace std;
int main() {
 vector<double> lc1(32,-1);
 vector<double> lc2(64,-1);


 double lc1Time = 20;
 double lc2Time = 60;
 double mainMemoryTime = 120;
 double totalHits = 0;
 double lc1Hits = 0;
 double lc2Hits = 0;
 double count = 0;
 int fr1 = -1;
 int re1 = 0;
 int fr2 = -1;
 int re2 = 0;
 char key = 100;
 srand(time(0));
 cout<<"Sequential Memory Organization:"<<endl<<endl;
 cout<<" "<<"Requirement"<<setw(22)<<"Location of Hit"<<" "<<setw(15)<<"Avg.
Access Time"<<endl;
 while(key--) {
 count++;
```

```
 double avgTime = 0;
 double input = rand()%512;
 bool f1 = false;
 bool f2 = false;
 for(double i=0; i<32; i++) {
 if(lc1[i]==input) {
 lc1Hits++;
 f1 = true;
 f2 = true;
 avgTime += (lc1Hits/(count))*lc1Time + (1-
(lc1Hits/(count)))*(lc2Hits/(count-lc1Hits))*(lc1Time+lc2Time) + (1-
(lc1Hits/(count)))*(1-(lc2Hits/(count
lc1Hits)))*1*(lc1Time+lc2Time+mainMemoryTime);


 cout<<setw(12)<<input<<" "<<setw(20)<<"L1 Cache"<<"
"<<setw(8)<<avgTime<<endl;
 }
 }
 if(!f1) {
 double b = input/2;
 for(double i=0; i<64; i++) {
 if(lc2[i]==b) {
 lc2Hits++;
 f2 = true;
 // found in 2
 if(re1==fr1) {
 re1 = (re1+1)%32;
 }
 fr1 = (fr1+1)%32;
 lc1[fr1] = input;
 avgTime += (lc1Hits/(count))*lc1Time + (1-
(lc1Hits/(count)))*(lc2Hits/(count-lc1Hits))*(lc1Time+lc2Time) + (1-
(lc1Hits/(count)))*(1-(lc2Hits/(count
lc1Hits)))*1*(lc1Time+lc2Time+mainMemoryTime);
 cout<<setw(12)<<input<<" "<<setw(20)<<"L2 Cache"<<"  "<<setw(8)<<avgTime<<endl;
 }
 }
 }
 if(!f2) {
 double b = input/2;
 if(re2==fr2) {
 re2 = (re2+1)%64;
 }
 fr2 = (fr2+1)%64;
 lc2[fr2] = b;
 if(re1==fr1) {
 re1 = (re1+1)%32;
```

```
 }


 fr1 = (fr1+1)%32;
 lc1[fr1] = input;
 avgTime += (lc1Hits/(count))*lc1Time + (1-
(lc1Hits/(count)))*(lc2Hits/(count-lc1Hits))*(lc1Time+lc2Time) + (1-
(lc1Hits/(count)))*(1-(lc2Hits/(count
lc1Hits)))*1*(lc1Time+lc2Time+mainMemoryTime);
 cout<<setw(12)<<input<<" "<<setw(20)<<"Main Memory"<<"
"<<setw(8)<<avgTime<<endl;
 }
 }
 cout<<endl;
 cout<<"L1 Hit Ratio (H1) = "<<lc1Hits<<"/"<<count<<" =
"<<(double)lc1Hits/count<<endl;
 cout<<"L1 Access Time (T1) = "<<lc1Time<<" ns"<<endl<<endl;
 cout<<"L2 Hit Ratio (H2) = "<<lc2Hits<<"/"<<(count-lc1Hits)<<" =
"<<(double)lc2Hits/(count-lc1Hits)<<endl;
 cout<<"L2 Access Time (T2) = "<<lc2Time<<" ns"<<endl<<endl;
 cout<<"Main Memory Hit Ratio (Hm) = "<<1<<endl;
 cout<<"Main memory Access Time = "<<mainMemoryTime<<" ns"<<endl<<endl;
 cout<<"Average Access Time = [H1*T1] + [(1-H1)*H2*(T1+T2)] + [(1-H1)*(1-
H2)*Hm*(T1+T2+Tm)]"<<endl;
 double finalAns = ((double)lc1Hits/count)*lc1Time + (1-
((double)lc1Hits/count))*((double)lc2Hits/(100-lc1Hits))*(lc1Time+lc2Time) + (1-
((double)lc1Hits/count))*(1-((double)lc2Hits/(count
lc1Hits)))*1*(lc1Time+lc2Time+mainMemoryTime);
 cout<<"Average Access Time = "<<finalAns<<" ns"<<endl;

 return 0;
}
```

**Output:**

```
Sequential Memory Organization:
Requirement Location of Hit Avg. Access Time
 353 Main Memory 200
 372 Main Memory 200
 89 Main Memory 200
 189 Main Memory 200
 265 Main Memory 200
 423 Main Memory 200
 379 Main Memory 200
 107 Main Memory 200
 8 Main Memory 200
 217 Main Memory 200
```

```
155 Main Memory 200
294 Main Memory 200
192 Main Memory 200
47 Main Memory 200
348 Main Memory 200
217 L1 Cache 188.75
264 Main Memory 189.412
375 Main Memory 190
100 Main Memory 190.526
351 Main Memory 191
476 Main Memory 191.429
12 Main Memory 191.818
178 Main Memory 192.174
138 Main Memory 192.5
338 Main Memory 192.8
250 Main Memory 193.077
306 Main Memory 193.333
363 Main Memory 193.571
208 Main Memory 193.793
99 Main Memory 194
143 Main Memory 194.194
205 Main Memory 194.375
381 Main Memory 194.545
34 Main Memory 194.706
329 Main Memory 194.857
259 Main Memory 195
245 Main Memory 195.135
429 Main Memory 195.263
7 Main Memory 195.385
228 Main Memory 195.5
65 Main Memory 195.61
320 Main Memory 195.714
46 Main Memory 195.814
19 Main Memory 195.909
262 Main Memory 196
56 Main Memory 196.087
178 L1 Cache 192.34
132 Main Memory 192.5


252 Main Memory 192.653
189 L2 Cache 190.4
301 Main Memory 190.588
315 Main Memory 190.769
418 Main Memory 190.943
163 Main Memory 191.111
302 Main Memory 191.273
87 Main Memory 191.429
```

```
49 Main Memory 191.579
402 Main Memory 191.724
467 Main Memory 191.864
80 Main Memory 192
462 Main Memory 192.131
101 Main Memory 192.258
410 Main Memory 192.381
125 Main Memory 192.5
3 Main Memory 192.615
465 Main Memory 192.727
116 Main Memory 192.836
217 L2 Cache 191.176
368 Main Memory 191.304
71 Main Memory 191.429
27 Main Memory 191.549
262 L1 Cache 189.167
190 Main Memory 189.315
283 Main Memory 189.459
166 Main Memory 189.6
146 Main Memory 189.737
469 Main Memory 189.87
229 Main Memory 190
347 Main Memory 190.127
122 Main Memory 190.25
335 Main Memory 190.37
296 Main Memory 190.488
452 Main Memory 190.602
492 Main Memory 190.714
44 Main Memory 190.824
305 Main Memory 190.93
261 Main Memory 191.034
81 Main Memory 191.136
455 Main Memory 191.236
66 Main Memory 191.333
364 Main Memory 191.429
139 Main Memory 191.522
8 Main Memory 191.613
240 Main Memory 191.702
74 Main Memory 191.789
379 Main Memory 191.875
476 Main Memory 191.959
458 Main Memory 192.041
1 Main Memory 192.121
455 L1 Cache 190.4
L1 Hit Ratio (H1) = 4/100 = 0.04
L1 Access Time (T1) = 20 ns
```

```
L2 Hit Ratio (H2) = 2/96 = 0.0208333
L2 Access Time (T2) = 60 ns
Main Memory Hit Ratio (Hm) = 1
Main memory Access Time = 120 ns
Average Access Time = [H1*T1] + [(1-H1)*H2*(T1+T2)] + [(1-H1)*(1-
H2)*Hm*(T1+T2+Tm)]
Average Access Time = 190.4 ns
```

**Conclusion:**

We learnt about sequential memory organization and implemented it in C++ programming language successfully on the given problem statement in a 2-Level Cache Memory architecture for 100 different number words required by the processor.

# EXPERIMENT - 5

**AIM:** To simulates a direct-mapped cache

**Submission Sheet**

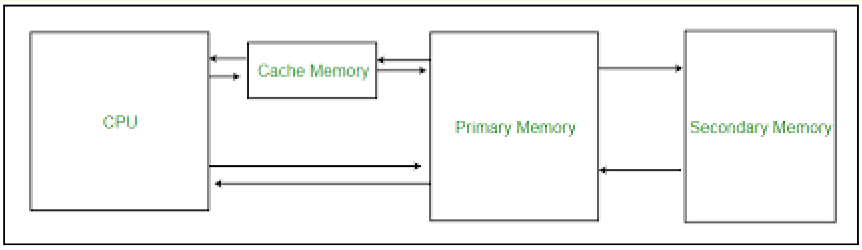
| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 17-12-2021 | 17-12-2021 | |

## THEORY:

cache memory, also called cache, supplementary memory system that temporarily stores frequently used instructions and data for quicker processing by the central processing unit (CPU) of a computer. The cache augments, and is an extension of, a computer's main memory. Both main memory and cache are internal random-access memories (RAMs) that use semiconductor-based transistor circuits. Cache holds a copy of only the most frequently used information or program codes stored in the main memory. The smaller capacity of the cache reduces the time required to locate data within it and provide it to the CPU for processing.

When a computer's CPU accesses its internal memory, it first checks to see if the information it needs is stored in the cache. If it is, the cache returns the data to the CPU. If the information is not in the cache, the CPU retrieves it from the main memory. Disk cache memory operates similarly, but the cache is used to hold data that have recently been written on, or retrieved from, a magnetic disk or other external storage device.

```
Hit ratio = hit / (hit + miss) = no. of hits/total accesses.
```

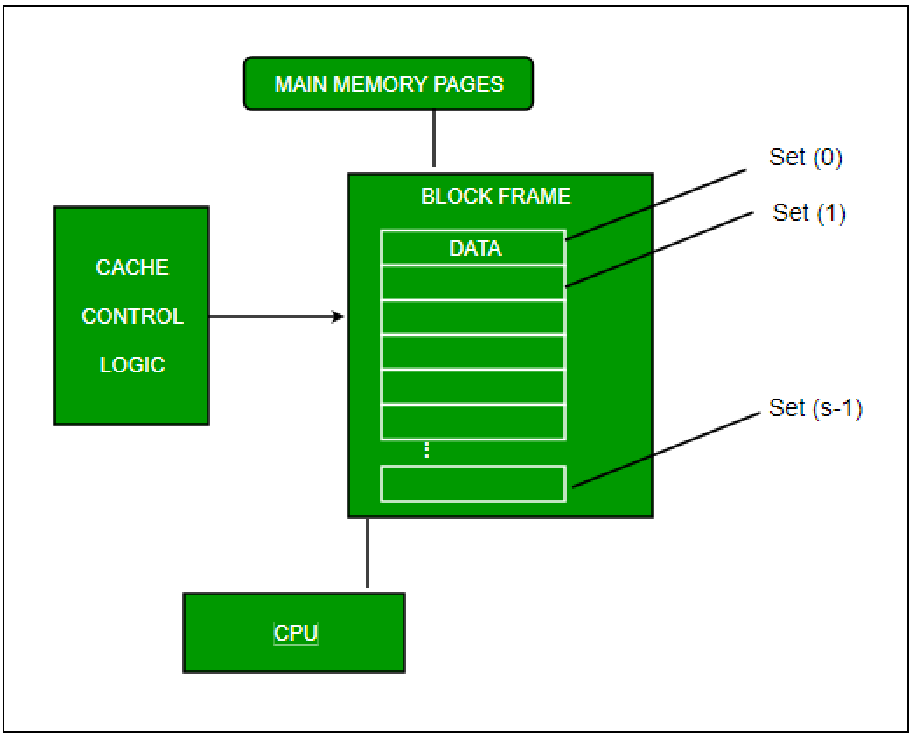



**DIRECT CACHE MAPPING:**

The simplest technique, known as direct mapping, maps each block of main memory into only one possible cache line. or
In Direct mapping, assign each memory block to a specific line in the cache. If a line is previously taken up by a memory block when a new block needs to be loaded, the old block is trashed. An address space is split into two parts: index field and a tag field. The cache is used to store the tag field whereas the rest is stored in the main memory. Direct mapping`s performance is directly proportional to the Hit ratio.

```
i = j modulo m
where
i=cache line number
j= main memory block number
m=number of lines in the cache
```

For purposes of cache access, each main memory address can be viewed as consisting of three fields. The least significant w bits identify a unique word or byte within a block of main memory. In most contemporary machines, the address is at the byte level. The remaining s bits specify one of the 2s blocks of main memory. The cache logic interprets these s bits as a tag of s-r bits (most significant portion) and a line field of r bits. This latter field identifies one of the m=2r lines of the cache.




## 8 Bit:

CODE:

```
#include <stdio.h>

int tag[8];

int main( )
{
   int addr;
   int i, j, t;
   int hits, accesses;
   FILE *fp;

   fp = fopen("trace.txt", "r");
   hits = 0;
   accesses = 0;
   while (fscanf(fp, "%x", &addr) > 0) {
      /* simulate a direct-mapped cache with 8 words */
      accesses += 1;
      printf("%3d: 0x%08x ", accesses, addr);
      i = (addr >> 2) & 7;
      t = addr | 0x1f;
      if (tag[i] == t) {
         hits += 1;
         printf("Hit%d ", i);
      } else {
         /* allocate entry */
         printf("Miss ");
         tag[i] = t;
      }
      for (i = 0; i < 8; i++)
         printf("0x%08x ", tag[i]);
      printf("\n");
   }
   printf("Hits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
   close(fp);
}
```

**OUTPUT:**

```
1: 0x80000000 Miss 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  2: 0x80000004 Miss 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
```

```
 3: 0x80000008 Miss 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 4: 0x8000000c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
 5: 0x00000020 Miss 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
 6: 0x80000010 Miss 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000
 7: 0x80000014 Miss 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000
 8: 0x80000018 Miss 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
 9: 0x8000000c Hit3 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
10: 0x00000024 Miss 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
11: 0x80000010 Hit4 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
12: 0x80000014 Hit5 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
13: 0x80000018 Hit6 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
14: 0x8000000c Hit3 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
15: 0x00000028 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
16: 0x80000010 Hit4 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
17: 0x80000014 Hit5 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
18: 0x80000018 Hit6 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
19: 0x8000000c Hit3 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
20: 0x0000002c Miss 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x00000000
21: 0x80000010 Hit4 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x00000000
22: 0x80000014 Hit5 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x00000000
23: 0x80000018 Hit6 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x00000000
24: 0x8000000c Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
25: 0x00000030 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x0000003f 0x8000001f 0x8000001f 0x00000000
26: 0x80000010 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
27: 0x80000014 Hit5 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
28: 0x80000018 Hit6 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
29: 0x8000000c Hit3 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
30: 0x00000034 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x0000003f 0x8000001f 0x00000000
31: 0x80000010 Hit4 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x0000003f 0x8000001f 0x00000000
32: 0x80000014 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
33: 0x80000018 Hit6 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
34: 0x8000000c Hit3 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
35: 0x00000038 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x0000003f 0x00000000
36: 0x80000010 Hit4 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x0000003f 0x00000000
37: 0x80000014 Hit5 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x0000003f 0x00000000
38: 0x80000018 Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
39: 0x8000000c Hit3 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
40: 0x0000003c Miss 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
41: 0x80000010 Hit4 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
42: 0x80000014 Hit5 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
43: 0x80000018 Hit6 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
44: 0x8000000c Hit3 0x0000003f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
45: 0x00000040 Miss 0x0000005f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
46: 0x80000010 Hit4 0x0000005f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
47: 0x80000014 Hit5 0x0000005f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
48: 0x80000018 Hit6 0x0000005f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
49: 0x8000000c Hit3 0x0000005f 0x0000003f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
50: 0x00000044 Miss 0x0000005f 0x0000005f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
51: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
52: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
53: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
54: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000003f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
55: 0x00000048 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
56: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
57: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
58: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
59: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
60: 0x0000004c Miss 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
61: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
62: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
63: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
64: 0x8000000c Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
65: 0x00000050 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x0000005f 0x8000001f 0x8000001f 0x0000003f
66: 0x80000010 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
67: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
68: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
69: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
70: 0x00000054 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x0000005f 0x8000001f 0x0000003f
71: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x0000005f 0x8000001f 0x0000003f
```

```
 72: 0x80000014 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
 73: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
 74: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
 75: 0x00000058 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x0000003f
 76: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x0000003f
 77: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x0000003f
 78: 0x80000018 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
 79: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000003f
 80: 0x0000005c Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 81: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 82: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 83: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 84: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 85: 0x00000060 Miss 0x0000007f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 86: 0x80000010 Hit4 0x0000007f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 87: 0x80000014 Hit5 0x0000007f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 88: 0x80000018 Hit6 0x0000007f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 89: 0x8000000c Hit3 0x0000007f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 90: 0x00000064 Miss 0x0000007f 0x0000007f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 91: 0x80000010 Hit4 0x0000007f 0x0000007f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 92: 0x80000014 Hit5 0x0000007f 0x0000007f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 93: 0x80000018 Hit6 0x0000007f 0x0000007f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 94: 0x8000000c Hit3 0x0000007f 0x0000007f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 95: 0x00000068 Miss 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 96: 0x80000010 Hit4 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 97: 0x80000014 Hit5 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 98: 0x80000018 Hit6 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
 99: 0x8000000c Hit3 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
100: 0x0000006c Miss 0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
101: 0x80000010 Hit4 0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
102: 0x80000014 Hit5 0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
103: 0x80000018 Hit6 0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
Hits = 68, Accesses = 103, Hit ratio = 0.660194
```

---

## 16 Bit:

CODE:

```
#include <stdio.h>

int tag[16];

int main( )
{
   int addr;
   int i, j, t;
   int hits, accesses;
   FILE *fp;

   fp = fopen("trace.txt", "r");
   hits = 0;
   accesses = 0;
```

```
    while (fscanf(fp, "%x", &addr) > 0) {
        /* simulate a direct-mapped cache with 8 words */
        accesses += 1;
        printf("%3d: 0x%08x ", accesses, addr);
        i = (addr >> 2) & 15;
        t = addr | 0x1f;
        if (tag[i] == t) {
            hits += 1;
            printf("Hit%d ", i);
        } else {
            /* allocate entry */
            printf("Miss ");
            tag[i] = t;
        }
        for (i = 0; i < 16; i++)
            printf("0x%08x ", tag[i]);
        printf("\n");
    }
    printf("Hits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
    close(fp);
}
```

## OUTPUT:

```
 1: 0x80000000 Miss 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  2: 0x80000004 Miss 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  3: 0x80000008 Miss 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  4: 0x8000000c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  5: 0x00000020 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  6: 0x80000010 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  7: 0x80000014 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  8: 0x80000018 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
  9: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 10: 0x00000024 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 11: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 12: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 13: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 14: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
```

```
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 15: 0x00000028 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 16: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 17: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 18: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 19: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
 20: 0x0000002c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
 21: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
 22: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
 23: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
 24: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
 25: 0x00000030 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
 26: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
 27: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
 28: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
 29: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
 30: 0x00000034 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
 31: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
 32: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
 33: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
 34: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
 35: 0x00000038 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000
 36: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000
 37: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000
 38: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000
 39: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000
 40: 0x0000003c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 41: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 42: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 43: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 44: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 45: 0x00000040 Miss 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 46: 0x80000010 Hit4 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 47: 0x80000014 Hit5 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 48: 0x80000018 Hit6 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
```

```
 49: 0x8000000c Hit3 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 50: 0x00000044 Miss 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 51: 0x80000010 Hit4 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 52: 0x80000014 Hit5 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 53: 0x80000018 Hit6 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 54: 0x8000000c Hit3 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 55: 0x00000048 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 56: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 57: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 58: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 59: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 60: 0x0000004c Miss 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 61: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 62: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 63: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 64: 0x8000000c Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 65: 0x00000050 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x0000005f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 66: 0x80000010 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 67: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 68: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 69: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 70: 0x00000054 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x0000005f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 71: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x0000005f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 72: 0x80000014 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 73: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 74: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 75: 0x00000058 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 76: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 77: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x0000005f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 78: 0x80000018 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 79: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 80: 0x0000005c Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 81: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 82: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 83: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
```

```
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 84: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 85: 0x00000060 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 86: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 87: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 88: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 89: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 90: 0x00000064 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 91: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 92: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 93: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 94: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 95: 0x00000068 Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 96: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 97: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 98: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
 99: 0x8000000c Hit3 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
100: 0x0000006c Miss 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
101: 0x80000010 Hit4 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
102: 0x80000014 Hit5 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
103: 0x80000018 Hit6 0x0000005f 0x0000005f 0x0000005f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x0000005f
0x0000007f 0x0000007f 0x0000007f 0x0000007f 0x0000003f 0x0000003f 0x0000003f 0x0000003f
Hits = 72, Accesses = 103, Hit ratio = 0.699029
```

## 32 Bit:

CODE:

```
#include <stdio.h>
#include <stdio.h>
int tag[32];
 int main( )
{
        int addr;
        int i, j, t;
        int hits, accesses;
        FILE *fp;

        fp = fopen("trace.txt", "r");
        hits = 0;
        accesses = 0;
        while (fscanf(fp, "%x", &addr) > 0) {
        /* simulate a direct-mapped cache with 8 words */
          accesses += 1;
     printf("%3d: 0x%08x ", accesses, addr);
        i = (addr >> 2) & 31;
        t = addr | 0x1f;
        if (tag[i] == t) {
        hits += 1;
        printf("Hit%d ", i);
        } else {
        /* allocate entry */
        printf("Miss ");
        tag[i] = t;
        }
        for (i = 0; i < 32; i++)
        printf("0x%08x ", tag[i]);
     printf("\n");
        }
   printf("Hits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
        close(fp);
}
```

**OUTPUT:**

```
1: 0x80000000 Miss 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  2: 0x80000004 Miss 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  3: 0x80000008 Miss 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  4: 0x8000000c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  5: 0x00000020 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  6: 0x80000010 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  7: 0x80000014 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  8: 0x80000018 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
  9: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 10: 0x00000024 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 11: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 12: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 13: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 14: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 15: 0x00000028 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 16: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 17: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
```

```
0x00000000 0x00000000 0x00000000 0x00000000
 18: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 19: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 20: 0x0000002c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 21: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 22: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 23: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 24: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 25: 0x00000030 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 26: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 27: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 28: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 29: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 30: 0x00000034 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 31: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 32: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 33: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 34: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
```

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 35: 0x00000038 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 36: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 37: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 38: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 39: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 40: 0x0000003c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 41: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 42: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 43: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 44: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 45: 0x00000040 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 46: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 47: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 48: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 49: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 50: 0x00000044 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 51: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 52: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
```

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0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 53: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 54: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 55: 0x00000048 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 56: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 57: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 58: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 59: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 60: 0x0000004c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 61: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 62: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 63: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 64: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 65: 0x00000050 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 66: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
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0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 67: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 68: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 69: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
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0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
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0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 71: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 72: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 73: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 74: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 75: 0x00000058 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 76: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 77: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 78: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 79: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 80: 0x0000005c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 81: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 82: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 83: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 84: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 85: 0x00000060 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 86: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x00000000 0x00000000 0x00000000
```

```
0x00000000 0x00000000 0x00000000 0x00000000
 87: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 88: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 89: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 90: 0x00000064 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 91: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 92: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 93: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 94: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 95: 0x00000068 Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 96: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 97: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 98: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
 99: 0x8000000c Hit3 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
100: 0x0000006c Miss 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x0000007f
0x00000000 0x00000000 0x00000000 0x00000000
101: 0x80000010 Hit4 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x0000007f
0x00000000 0x00000000 0x00000000 0x00000000
102: 0x80000014 Hit5 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x0000007f
0x00000000 0x00000000 0x00000000 0x00000000
103: 0x80000018 Hit6 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x8000001f 0x00000000
0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000003f 0x0000005f 0x0000005f
0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000005f 0x0000007f 0x0000007f 0x0000007f 0x0000007f
0x00000000 0x00000000 0x00000000 0x00000000
```

```
Hits = 76, Accesses = 103, Hit ratio = 0.737864
```

---

## Comparison Table

| Number of Bits | Hits | Accesses | Hit Ratio |
|---|---|---|---|
| 8 | 68 | 103 | 0.660194 |
| 16 | 72 | 103 | 0.699029 |
| 32 | 76 | 103 | 0.737864 |

---

## CONCLUSION:

Cache memory is the closest to the CPU, it reduces the access time from Main Memory. There are 3 ways to map cache to Main memory: Direct mapping, Associative mapping, and Set-Associative mapping. In Direct mapping, each memory block is assigned to a specific line in the cache. It is a simple way to map blocks but it has a lower cache hit ratio, as there is only one cache line available in a set. Every time a new memory is referenced to the same set, the cache line is replaced, this is the drawback of Direct Mapping.
As seen from the comparison table above which is derived from our program output, as we go on increasing the number of bits in cache memory, the hit ratio also increases.

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# EXPERIMENT - 6

## Aim

To implement fully associative mapping and set associative mapping.

**Submission Sheet**

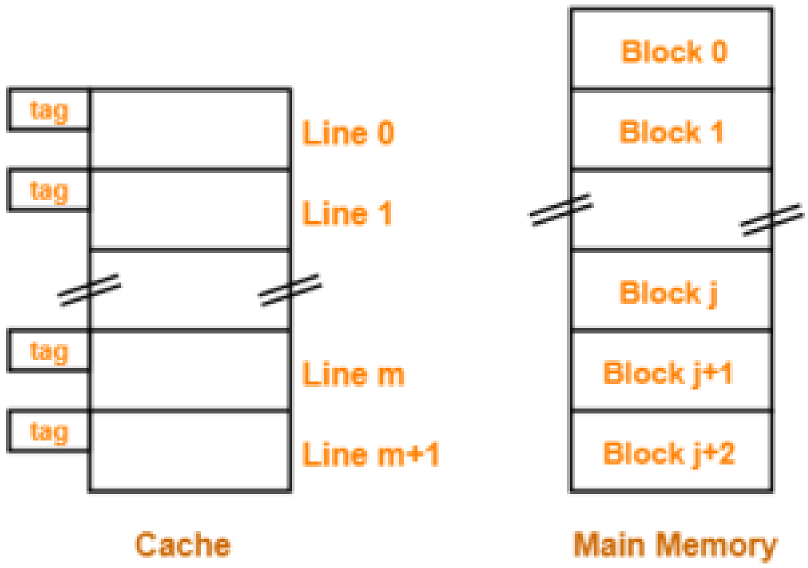
| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 6-11-2021 | 6-11-2021 | |

## Theory

A CPU cache is a hardware used by the central processing unit (CPU) of a computer to reduce the average cost (time) of accessing data from the main memory. A cache is a smaller, faster memory, located closer to a processor core, which stores copies of the data from frequently used main memory locations. Cache memory is costlier than main memory or disk memory but economical than CPU registers. It is an extremely fast memory type that acts as a buffer between RAM and the CPU, and holds frequently requested data and instructions so that they are immediately available to the CPU when needed.

**Fully associative mapping**

Fully Associative Mapping is a cache mapping technique that allows to map a block of main memory to any freely available cache line. In this type of mapping, the associative memory is used to store content and addresses of the memory word. Any block can go into any line of the cache. This means that the word id bits are used to identify which word in the block is needed, but the tag becomes all of the remaining bits. This enables the placement of any word at any place in the cache memory. It is considered to be the fastest and the most flexible mapping form.

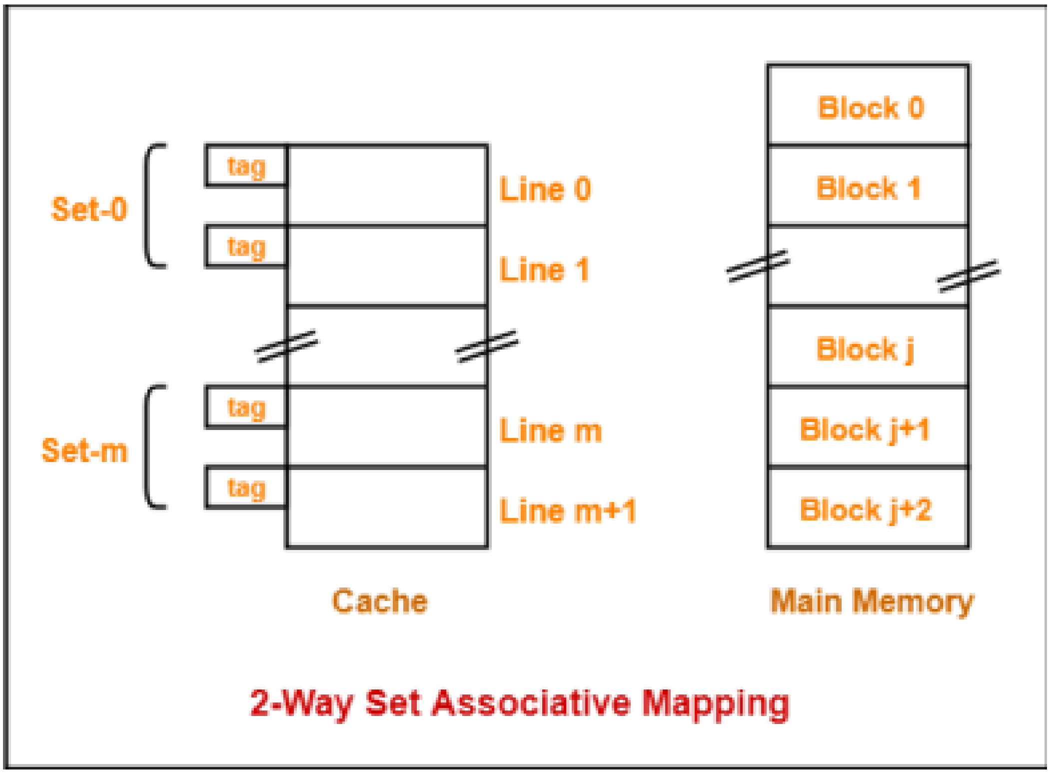



Fully Associative Mapping

**Set associative mapping**

Set-associative cache is a trade-off between direct-mapped cache and fully associative cache. This form of mapping is an enhanced form of direct mapping where the drawbacks of direct

mapping is removed. Set associative addresses the problem of possible thrashing in the direct mapping method. It does this by saying that instead of having exactly one line that a block can map to in the cache, we will group a few lines together creating a ***set***. Then a block in memory can map to any one of the lines of a specific sea. Set-associative mapping allows that each word that is present in the cache can have two or more words in the main memory for the same index address. Set associative cache mapping combines the best of direct and associative cache mapping techniques.




__**Prelab code for generating trace file**__

```
main: addu $t0,$0,$0
 addiu $t1,$0,80
 addu $t2,$0,$0
loop: lw $t3,array($t0)
 addu $t2,$t2,$t3
```

```
 addiu $t0,$t0,4
 bne $t0,$t1,loop
*done: beq $0,$0,done
array: .word 1,2,3,4,5,6,7,8,9,10
 .word 11,12,13,14,15,16,17,18,19,20
```

**Fully Associative Mapping – 8 bit**
**Code:**

```
#include <stdio.h>
int tag[8];
int mru[8] = {7,6,5,4,3,2,1,0};
void mruUpdate(int index)
{
int i;
// find index in mru
for (i = 0; i < 8; i++)
if (mru[i] == index)
break;
// move earlier refs one later
while (i > 0) {
mru[i] = mru[i-1];
i--;
}
mru[0] = index;


}
int main( )
{
int addr;
int i, j, t;
int hits, accesses;
FILE *fp;
fp = fopen("trace.txt", "r");
hits = 0;
accesses = 0;
while (fscanf(fp, "%x", &addr) > 0) {
/* simulate fully associative cache with 8 words */
accesses += 1;
printf("%3d: 0x%08x ", accesses, addr);
for (i = 0; i < 8; i++) {
if (tag[i] == addr) {
hits += 1;
printf("Hit%d ", i);
mruUpdate(i);
```

```
break;
}
}
if (i == 8) {
/* allocate entry */
printf("Miss ");
i = mru[7];
tag[i] = addr;
mruUpdate(i);
}
for (i = 0; i < 8; i++)
printf("0x%08x ", tag[i]);
for (i = 0; i < 8; i++)


printf("%d ", mru[i]);
printf("\n");
}
printf("Hits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
pclose(fp);
}
```

**Output:**

```
79: 0x0000000c Hit3 0x00000054 0x00000058 0x0000004c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 3 7 6 5 1 0 4 2
80: 0x0000005c Miss 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 2 3 7 6 5 1 0 4
81: 0x00000010 Hit5 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 5 2 3 7 6 1 0 4
82: 0x00000014 Hit6 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 6 5 2 3 7 1 0 4
83: 0x00000018 Hit7 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 7 6 5 2 3 1 0 4
84: 0x0000000c Hit3 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000050 0x00000010 0x00000014 0x00000018 3 7 6 5 2 1 0 4
85: 0x00000060 Miss 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 4 3 7 6 5 2 1 0
86: 0x00000010 Hit5 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 5 4 3 7 6 2 1 0
87: 0x00000014 Hit6 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 6 5 4 3 7 2 1 0
88: 0x00000018 Hit7 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 7 6 5 4 3 2 1 0
89: 0x0000000c Hit3 0x00000054 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 3 7 6 5 4 2 1 0
90: 0x00000064 Miss 0x00000064 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 0 3 7 6 5 4 2 1
91: 0x00000010 Hit5 0x00000064 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 5 0 3 7 6 4 2 1
92: 0x00000014 Hit6 0x00000064 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 6 5 0 3 7 4 2 1
93: 0x00000018 Hit7 0x00000064 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 7 6 5 0 3 4 2 1
94: 0x0000000c Hit3 0x00000064 0x00000058 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 3 7 6 5 0 4 2 1
95: 0x00000068 Miss 0x00000064 0x00000068 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 1 3 7 6 5 0 4 2
96: 0x00000010 Hit5 0x00000064 0x00000068 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 5 1 3 7 6 0 4 2
97: 0x00000014 Hit6 0x00000064 0x00000068 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 6 5 1 3 7 0 4 2
98: 0x00000018 Hit7 0x00000064 0x00000068 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 7 6 5 1 3 0 4 2
99: 0x0000000c Hit3 0x00000064 0x00000068 0x0000005c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 3 7 6 5 1 0 4 2
100: 0x0000006c Miss 0x00000064 0x00000068 0x0000006c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 2 3 7 6 5 1 0 4
101: 0x00000010 Hit5 0x00000064 0x00000068 0x0000006c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 5 2 3 7 6 1 0 4
102: 0x00000014 Hit6 0x00000064 0x00000068 0x0000006c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 6 5 2 3 7 1 0 4
103: 0x00000018 Hit7 0x00000064 0x00000068 0x0000006c 0x0000000c 0x00000060 0x00000010 0x00000014 0x00000018 7 6 5 2 3 1 0 4
Hits = 76, Accesses = 103, Hit ratio = 0.737864
```

**Fully Associative Mapping – 16 bit**

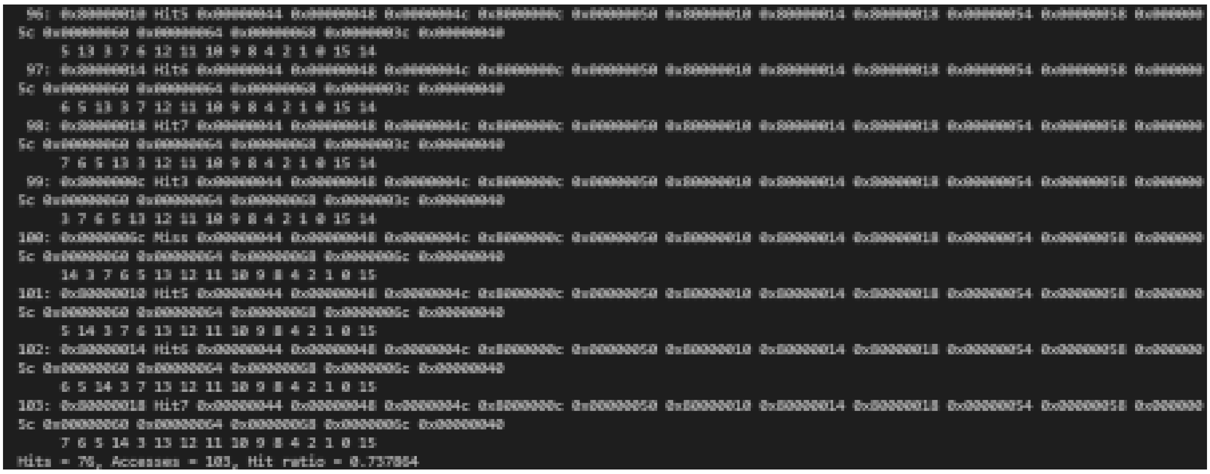
**Code:**

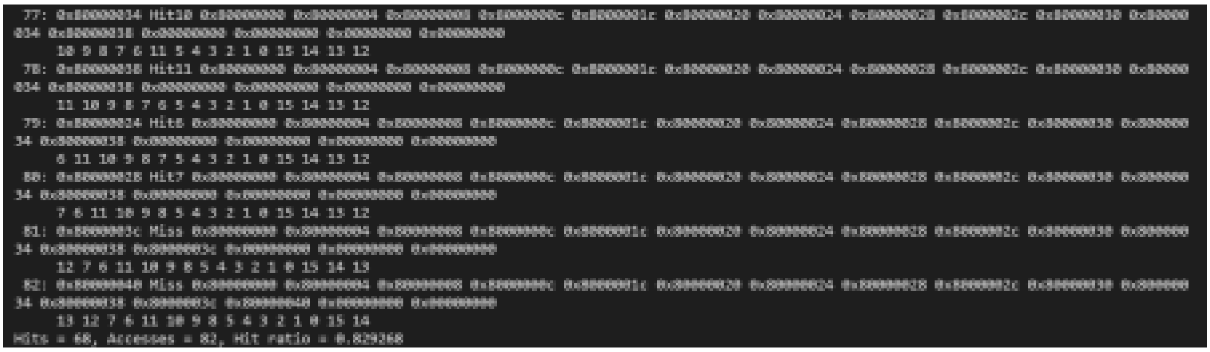
```
#include <stdio.h>
int tag[16];
int mru[16] = {15,14,13,12,11,10,9,8,7,6,5,4,3,2,1,0};
void mruUpdate(int index)
```

```
{
int i;
// find index in mru
for (i = 0; i < 16; i++)
if (mru[i] == index)
break;
// move earlier refs one later
while (i > 0) {
mru[i] = mru[i-1];


i--;
}
mru[0] = index;
}
int main( )
{
int addr;
int i, j, t;
int hits, accesses;
FILE *fp;
fp = fopen("trace.txt", "r");
hits = 0;
accesses = 0;
while (fscanf(fp, "%x", &addr) > 0) {
/* simulate fully associative cache with 16 words */
accesses += 1;
printf("%3d: 0x%08x ", accesses, addr);
for (i = 0; i < 16; i++) {
if (tag[i] == addr) {
hits += 1;
printf("Hit%d ", i);
mruUpdate(i);
break;
}
}
if (i == 16) {
/* allocate entry */
printf("Miss ");
i = mru[15];
tag[i] = addr;
mruUpdate(i);
}


for (i = 0; i < 16; i++)
printf("0x%08x ", tag[i]);
printf("\n ");
```

```
for (i = 0; i < 16; i++)
printf("%d ", mru[i]);
printf("\n");
}
printf("Hits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
close(fp);
}
```

## Output: Fully Associative Mapping – 16 bit



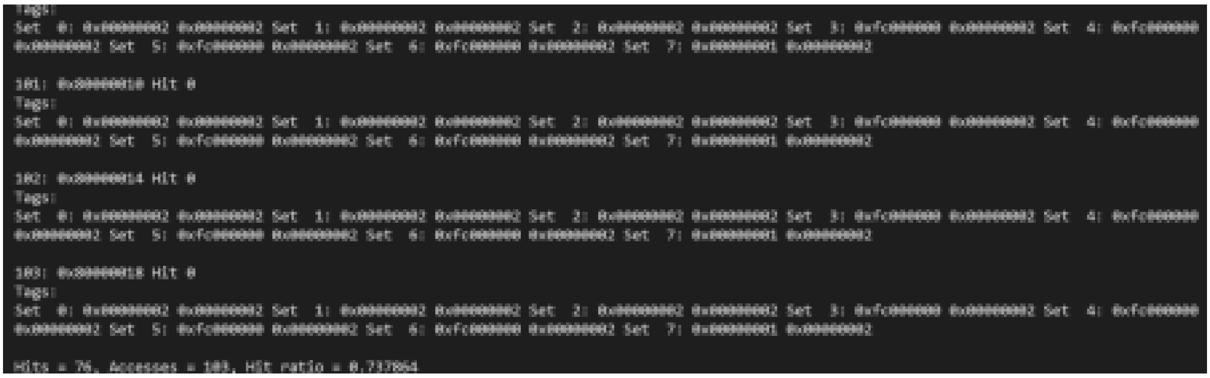

## Set Associative Mapping – 16 bit

## Code:

```c
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
void main() {
int** tags = malloc(2 * sizeof(int*));
tags[0] = malloc(16 * sizeof(int));
tags[1] = malloc(16 * sizeof(int));
int mru[8] = {1,1,1,1,1,1,1,1};
int sets = 8;
int addr;


int hits, accesses;
FILE *fp;
fp = fopen("trace.txt", "r");
hits = 0;
accesses = 0;
while (fscanf(fp, "%x", &addr) > 0) {
accesses++;
int setNum = (addr >> 2) & (int)(pow(2, log2(sets)) - 1);
```

```
int addrTag = addr >> (2 + (int)log2(sets));
printf("\n%3d: 0x%08x ", accesses, addr);
int i;
for(i = 0; i < 2; ++i) {
if(tags[i][setNum] == addrTag) {
printf("Hit %d", i);
hits++;
mru[setNum] = i;
break;
}
}
if(i == 2) {
printf("Miss");
tags[(mru[setNum] + 1) % 2][setNum] = addrTag;
mru[setNum] = (mru[setNum] + 1) % 2;
}
printf("\nTags:\n");
for(int i = 0; i < sets; ++i) {
printf("Set %2d: 0x%08x 0x%08x ", i, tags[0][i], tags[0][1]);
}
printf("\n");
}
printf("\nHits = %d, Accesses = %d, Hit ratio = %f\n", hits, accesses,
((float)hits)/accesses);
fclose(fp);
}
```

## Output: Set Associative Mapping – 16 bit



```
 78: 0x00000038 Hit 0
Tags:
Set  0: 0xfc000000 0xfc000000 Set  1: 0xfc000000 0xfc000000 Set  2: 0xfc000000 0xfc000000 Set  3: 0xfc000000 0xfc000000 Set  4: 0xfc000001
0xfc000000 Set  5: 0xfc000001 0xfc000000 Set  6: 0xfc000001 0xfc000000 Set  7: 0xfc000000 0xfc000000

 79: 0x00000024 Hit 1
Tags:
Set  0: 0xfc000000 0xfc000000 Set  1: 0xfc000000 0xfc000000 Set  2: 0xfc000000 0xfc000000 Set  3: 0xfc000000 0xfc000000 Set  4: 0xfc000001
0xfc000000 Set  5: 0xfc000001 0xfc000000 Set  6: 0xfc000001 0xfc000000 Set  7: 0xfc000000 0xfc000000

 80: 0x00000028 Hit 1
Tags:
Set  0: 0xfc000000 0xfc000000 Set  1: 0xfc000000 0xfc000000 Set  2: 0xfc000000 0xfc000000 Set  3: 0xfc000000 0xfc000000 Set  4: 0xfc000001
0xfc000000 Set  5: 0xfc000001 0xfc000000 Set  6: 0xfc000001 0xfc000000 Set  7: 0xfc000000 0xfc000000

 81: 0x0000003c Miss
Tags:
Set  0: 0xfc000000 0xfc000000 Set  1: 0xfc000000 0xfc000000 Set  2: 0xfc000000 0xfc000000 Set  3: 0xfc000000 0xfc000000 Set  4: 0xfc000001
0xfc000000 Set  5: 0xfc000001 0xfc000000 Set  6: 0xfc000001 0xfc000000 Set  7: 0xfc000000 0xfc000000

 82: 0x00000040 Miss
Tags:
Set  0: 0xfc000002 0xfc000000 Set  1: 0xfc000000 0xfc000000 Set  2: 0xfc000000 0xfc000000 Set  3: 0xfc000000 0xfc000000 Set  4: 0xfc000001
0xfc000000 Set  5: 0xfc000001 0xfc000000 Set  6: 0xfc000001 0xfc000000 Set  7: 0xfc000000 0xfc000000

Hits = 68, Accesses = 82, Hit ratio = 0.829268
```

## Conclusion

A cache is a smaller, quicker memory that stores copies of software instructions and data that are utilized regularly in the operation of programs and is positioned closer to the processor core. The program's overall speed is improved by having quick access to these commands. In this experiment, we learnt about fully associative mapping and set associative mapping and implemented them in a C program.

# EXPERIMENT - 7

**Aim**: Study and Simulate (Stepwise) Experiments of MIPS Programming available at MIPS simulator. Modify the given programs to implement
1) Add 10 nos.
2) to print message "Hello MIPS"
3) To Reverse the input string (e.g."ABC" - "CBA").

**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 26/11/21 | 26/11/21 | |

**Theory**:
MIPS assembly language simply refers to the assembly language of the MIPS processor. The term MIPS is an acronym for Microprocessor without Interlocked Pipeline Stages. It is a reduced-instruction set architecture developed by an organization called MIPS Technologies. The MIPS assembly language is a very useful language to learn because many embedded systems run on the MIPS processor.

**MIPS Architecture**
**Data Types**
1. All the instructions in MIPS are 32 bits.
2. A byte in the MIPS architecture represents 8 bits; a halfword represents 2 bytes (16 bits) and a word represents 4 bytes (32 bits).
3. Each character used in the MIPS architecture requires 1 byte of storage. Each integer used requires 4 bytes of storage.

**Literals**
In the MIPS architecture, literals represent all numbers (e.g. 5), characters enclosed in single quotes (e.g. ‘g’) and strings enclosed in double quotes (e.g. “Deadpool”).
Code 1: To add 10 numbers

**Registers**
MIPS architecture uses 32 general-purpose registers. Each register in this architecture is preceded by ‘$’ in the assembly language instruction. You can address these registers in one of two ways. Either use the register’s number (that is, from $0 to $31), or the register’s name (for example, $t1).

**MIPS Structure**

**General structure of a program created using the MIPS assembly language**
A typical program created using the MIPS assembly language has two main parts. They are the data declaration section of the program and the code section of the program.

**Data declaration section of a MIPS assembly language program**
The data declaration section of the program is the part of the program identified with the assembler directive .data. This is the part of the program in which all the variables to be used in the program are created and defined. It is also the part of the program where storage is allocated in the main memory (RAM). The MIPS assembly language program declares variables as follows: name: .storage_type value(s).

The “name” refers to the name of the variable being created. The “storage_type” refers to the type of data that the variable is meant to store. The “value(s)” refers to the information to be stored in the variable being created.

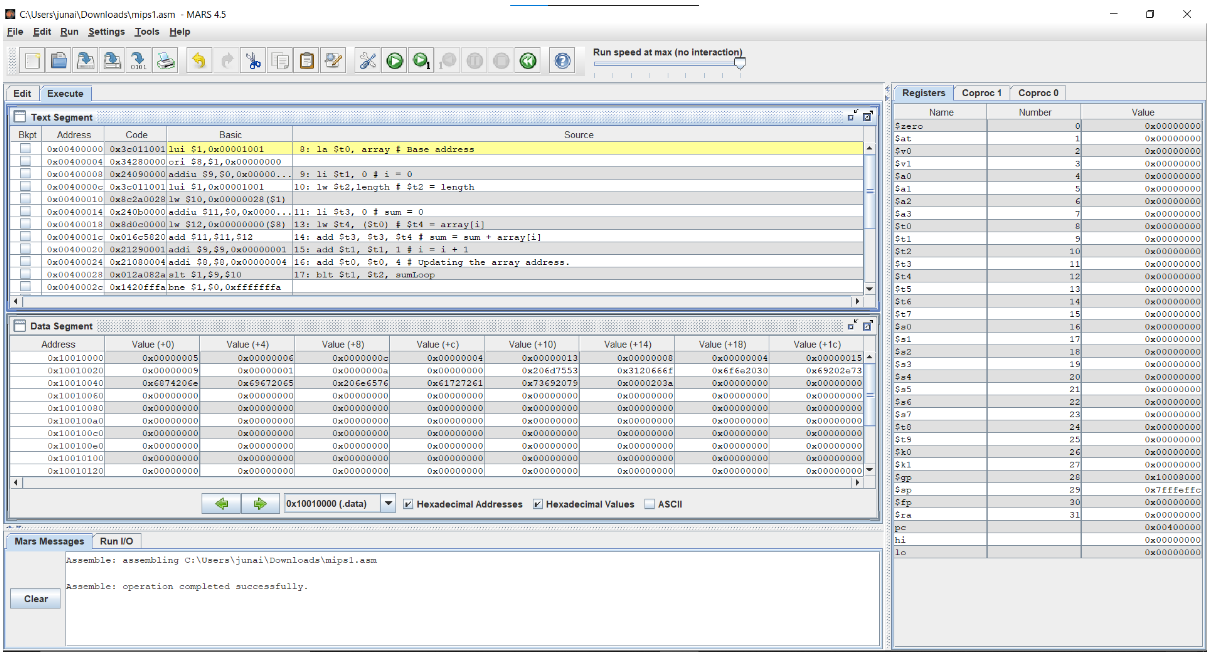
**Code section of the MIPS assembly language program**

The code section of the program is the part of the program in which the instructions to be executed by the program are written. It is placed in the section of the program identified with the assembler directive .text. The starting point for the code section of the program is marked with the label “main” and the ending point for the code section of the program is marked with an exit system call. This section of a MIPS assembly language program typically involves the manipulation of registers and the performance of arithmetic operations.

**CODE 1: Addition of 10 numbers**

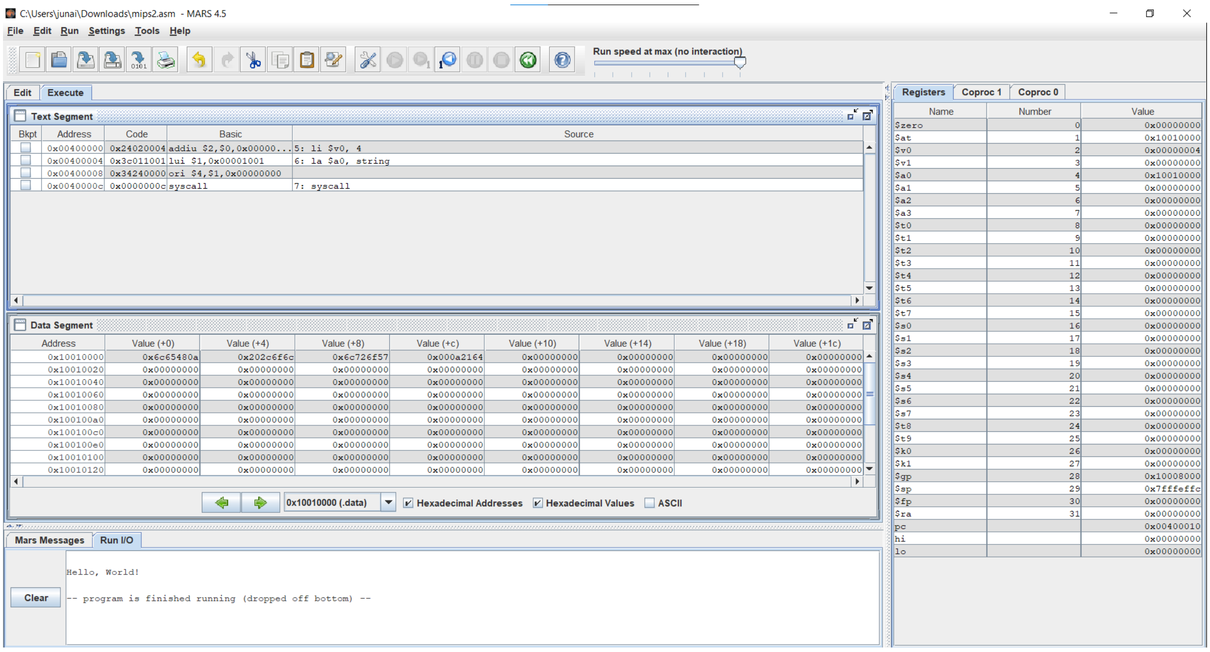
```
.data
array: .word 5,6,12,4,19,8,4,21,9,1
length: .word 10
sum: .word 0
myMessage: .ascii "Sum of 10 nos. in the given array is: "
.text
main:
la $t0, array # Base address
li $t1, 0 # i = 0
lw $t2,length # $t2 = length
li $t3, 0 # sum = 0
sumLoop:
lw $t4, ($t0) # $t4 = array[i]
add $t3, $t3, $t4 # sum = sum + array[i]
```

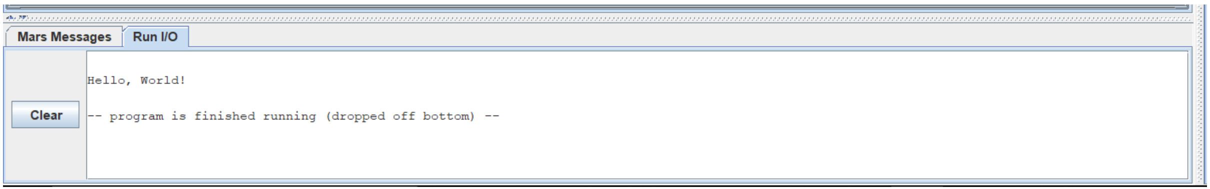
```
add $t1, $t1, 1 # i = i + 1
add $t0, $t0, 4 # Updating the array address.
blt $t1, $t2, sumLoop
sw $t3, sum
li $v0, 4
la $a0, myMessage
syscall
li $v0, 1
move $a0, $t3
syscall
```




**Code 2: To print Hello World**

```
.data
string: .asciiz "\nHello, World!\n"
.text
main:
li $v0, 4
la $a0, string
syscall
```



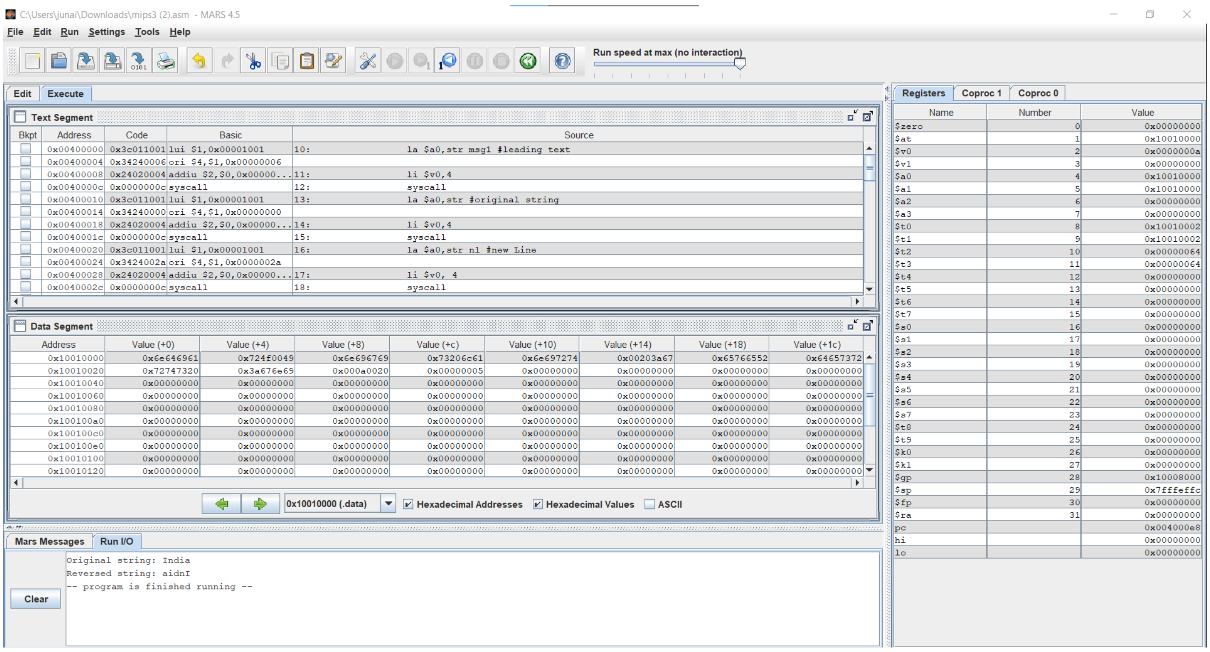



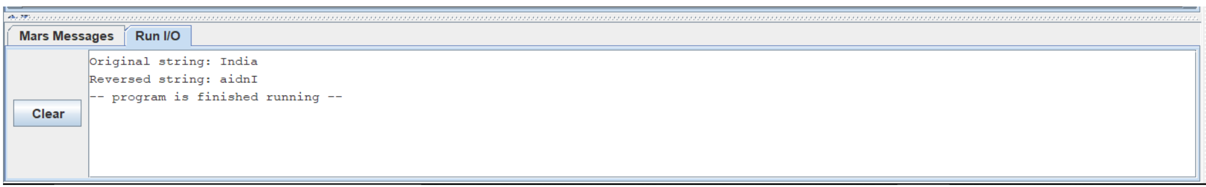

**CODE 3: To Reverse the input string (e.g."ABC" – "CBA").**

```
.data
        str: .asciiz "India"
        str_msg1: .asciiz "Original string: "
        str_msg2: .asciiz "Reversed string: "
        str_nl: .asciiz "\n"
        str_len: .word 0
.text
        main:
                #print original string
                la $a0,str_msg1 #leading text
                li $v0,4
                syscall
                la $a0,str #original string
                li $v0,4
```

```
syscall
la $a0,str_nl #new Line
li $v0, 4
syscall
#get length
add $t0,$zero,$zero #initialize registers when needed
add $a0,$zero,$zero
add $a1,$zero,$zero
la $a0,str #loads the address of the string
la $a1,str
getLen:
        lb $t0,0($a0) #load first byte
        beqz $t0,saveLen
        addi $a0,$a0,1
        j getLen #jump back to start of this loop
saveLen:
        subu $t0,$a0,$a1 #len = address of null terminator - str address
        sw $t0,str_len
#reverse the string
add $t0,$zero,$zero #address of the beginning of str
add $t1,$zero,$zero #address of the end of str
add $t2,$zero,$zero
add $t3,$zero,$zero
revString:
        #find the index of the last character before the end of the string
        la $t0,str #loads the address of the start of the string
        lw $t1,str_len #loads the length of the string
        addu $t1,$t0,$t1
        subi $t1,$t1,1
        loop:
                lb $t2,0($t0) #load the first character
                lb $t3,0($t1) #load the last character
                ble $t1,$t0,printRev
                sb $t3,0($t0)
                sb $t2,0($t1)
                addi $t0,$t0,1
                subi $t1,$t1,1 #and loop until we reach the middle
                j loop
#print the reversed version of the text
printRev:
        add $a0,$zero,$zero #initialize the a0 registry
        la $a0,str_msg2 #leading text
        li $v0,4
```

```
syscall
la $a0,str #reversed string
li $v0,4
syscall
li $v0,10 #exit program
syscall
```



# EXPERIMENT - 8

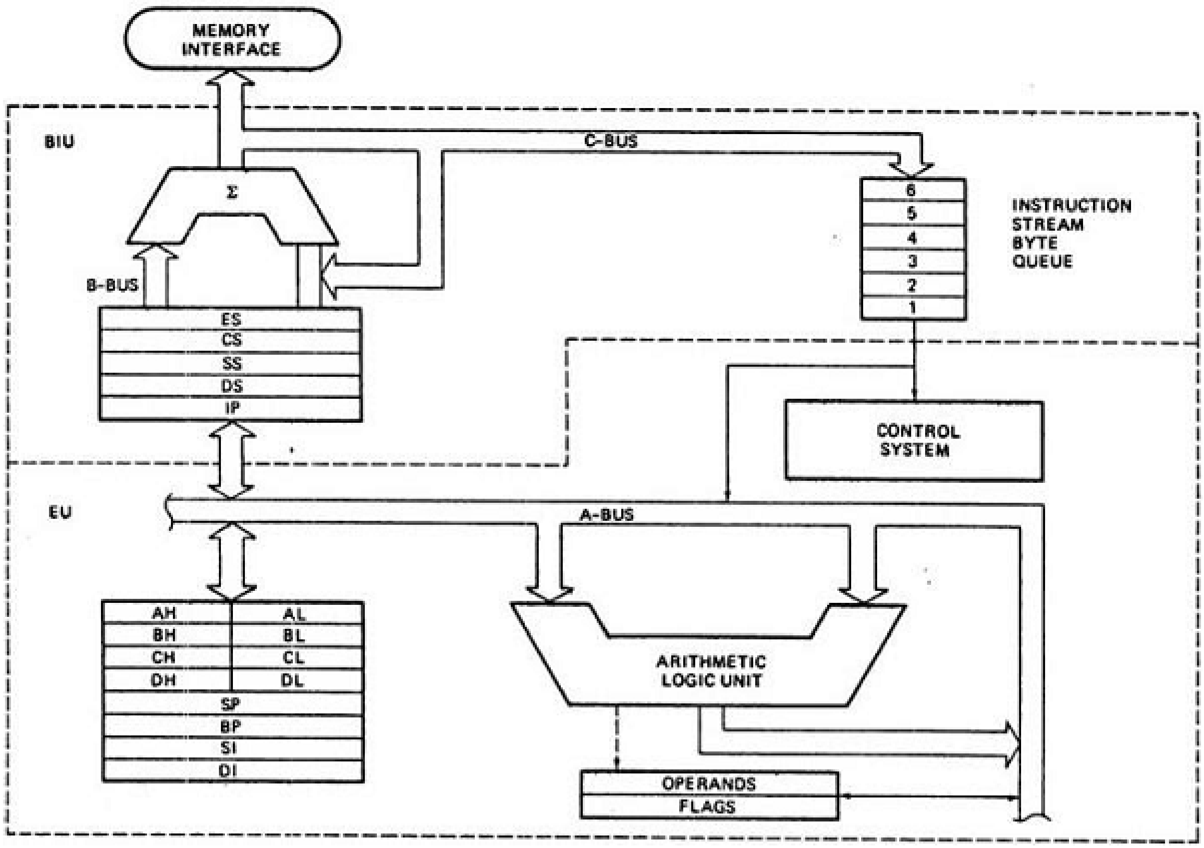
**Aim** : Run the simulator using the given link https://yjdoc2.github.io/8086-emulator-web/compile. Study and execute First 6 examples from the repository https://github.com/YJDoc2/8086-Emulator/tree/master/examples

**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 17/12/21 | 17/12/21 | |

## Architecture of 8086

The following diagram depicts the architecture of a 8086 Microprocessor −




**Pins on 8086:**

**AD0-AD15 (Address Data Bus):** Bidirectional address/data lines. These are low order address bus. They are multiplexed with data.
When these lines are used to transmit memory address, the symbol A is used instead of AD, for example, A0- A15.
**A16 - A19 (Output):** High order address lines. These are multiplexed with status signals.
**A16/S3, A17/S4: A16 and A17** are multiplexed with segment identifier signals S3 and S4.
**A18/S5: A18** is multiplexed with interrupt status S5.
**A19/S6: A19** is multiplexed with status signal S6.
**BHE/S7 (Output)**: Bus High Enable/Status. During T1, it is low. It enables the data onto the most significant half of the data bus, D8-D15. 8-bit devices connected to the upper half of the data bus use BHE signal. It is multiplexed with status signal S7. S7 signal is available during T3 and T4.
**RD** (Read): For read operation. It is an output signal. It is active when LOW.
**Ready** (Input): The addressed memory or I/O sends acknowledgment through this pin. When HIGH, it denotes that the peripheral is ready to transfer data.
**RESET** (Input): System reset. The signal is active HIGH.
**CLK** (input): Clock 5, 8 or 10 MHz.
**INTR**: Interrupt Request.
**NMI** (Input): Non-maskable interrupt request.
**TEST** (Input): Wait for test control. When LOW the microprocessor continues execution otherwise waits.
**VCC**: Power supply +5V dc.
**GND**: Ground.

## Operating Modes of 8086

There are two operating modes of operation for Intel 8086, namely the minimum mode and the maximum mode.
When only one 8086 CPU is to be used in a microprocessor system, the 8086 is used in the Minimum mode of operation.
In a multiprocessor system 8086 operates in the Maximum mode.

**ADDRESSING**:
The 8086 microprocessors have 8 addressing modes. Two addressing modes have been provided for instructions which operate on register or immediate data.
**These two addressing modes are:**

**Register Addressing**: In register addressing, the operand is placed in one of the 16-bit or 8-bit general purpose registers.
Example
- MOV AX, CX
- ADD AL, BL
- ADD CX, DX

**Immediate Addressing**: In immediate addressing, the operand is specified in the instruction itself.

Example

- MOV AL, 35H
- MOV BX, 0301H
- MOV [0401], 3598H
- ADD AX, 4836H

The remaining 6 addressing modes specify the location of an operand which is placed in a memory.

These 6 addressing modes are:

**Direct Addressing**: In direct addressing mode, the operand?s offset is given in the instruction as an 8-bit or 16-bit displacement element.

Example

- ADD AL, [0301]

The instruction adds the content of the offset address 0301 to AL. the operand is placed at the given offset (0301) within the data segment DS.

**Register Indirect Addressing**: The operand's offset is placed in any one of the registers BX, BP, SI or DI as specified in the instruction.

Example

- MOV AX, [BX]

It moves the contents of memory locations addressed by the register BX to the register AX.

**Based Addressing**: The operand's offset is the sum of an 8-bit or 16-bit displacement and the contents of the base register BX or BP. BX is used as base register for data segment, and the BP is used as a base register for stack segment.

Effective address (Offset) = [BX + 8-bit or 16-bit displacement].

Example

- MOV AL, [BX+05]; an example of 8-bit displacement.
- MOV AL, [BX + 1346H]; example of 16-bit displacement.

**Indexed Addressing**: The offset of an operand is the sum of the content of an index register SI or DI and an 8-bit or 16-bit displacement.

Offset (Effective Address) = [SI or DI + 8-bit or 16-bit displacement]

Example

- MOV AX, [SI + 05]; 8-bit displacement.
- MOV AX, [SI + 1528H]; 16-bit displacement.

**Based Indexed Addressing**: The offset of operand is the sum of the content of a base register BX or BP and an index register SI or DI.

Effective Address (Offset) = [BX or BP] + [SI or DI]

Here, BX is used for a base register for data segment, and BP is used as a base register for stack segment.

Example

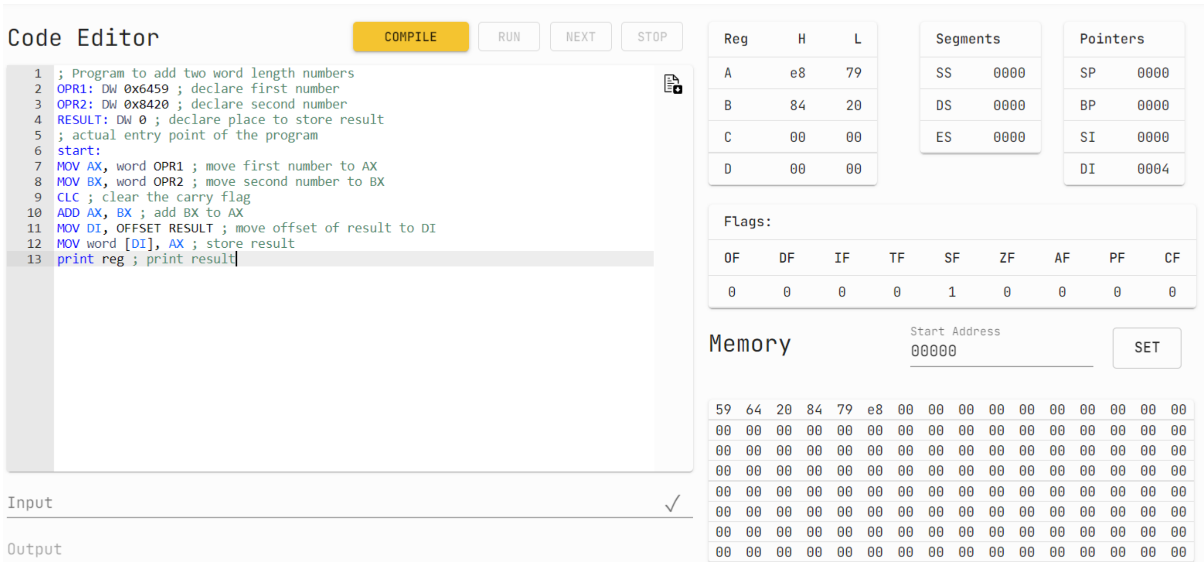
- ADD AX, [BX + SI]
- MOV CX, [BX + SI]

**Based Indexed with Displacement**: In this mode of addressing, the operand's offset is given by:
Effective Address (Offset) = [BX or BP] + [SI or DI] + 8-bit or 16-bit displacement
Example

- MOV AX, [BX + SI + 05]; 8-bit displacement
- MOV AX, [BX + SI + 1235H]; 16-bit displacement

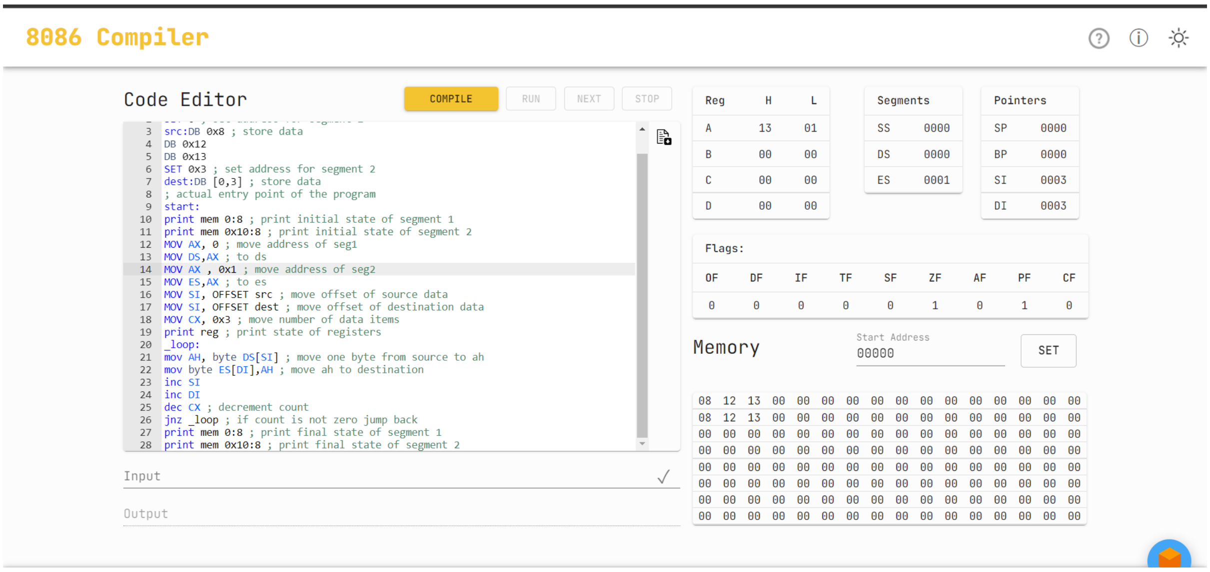
### 1. Program to add two word length number

```
; Program to add two word length numbers
OPR1: DW 0x6459 ; declare first number
OPR2: DW 0x8420 ; declare second number
RESULT: DW 0 ; declare place to store result
; actual entry point of the program
start:
MOV AX, word OPR1 ; move first number to AX
MOV BX, word OPR2 ; move second number to BX
CLC ; clear the carry flag
ADD AX, BX ; add BX to AX
MOV DI, OFFSET RESULT ; move offset of result to DI
MOV word [DI], AX ; store result
print reg ; print result
```



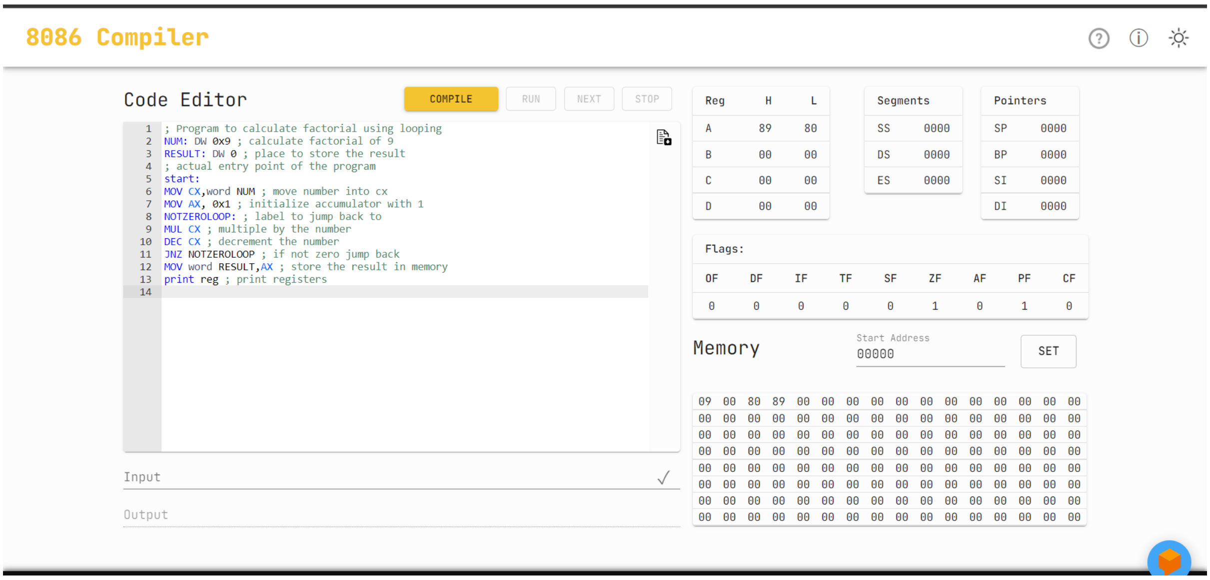
**2. A Program to move data from one segment to another.**

```
; A Program to move data from one segment to another
SET 0 ; set address for segment 1
src:DB 0x8 ; store data
DB 0x12
DB 0x13
SET 0x3 ; set address for segment 2
dest:DB [0,3] ; store data
; actual entry point of the program
start:
print mem 0:8 ; print initial state of segment 1
print mem 0x10:8 ; print initial state of segment 2
MOV AX, 0 ; move address of seg1
MOV DS,AX ; to ds
MOV AX , 0x1 ; move address of seg2
MOV ES,AX ; to es
MOV SI, OFFSET src ; move offset of source data
MOV SI, OFFSET dest ; move offset of destination data
MOV CX, 0x3 ; move number of data items
print reg ; print state of registers
_loop:
mov AH, byte DS[SI] ; move one byte from source to ah
mov byte ES[DI],AH ; move ah to destination
inc SI
inc DI
dec CX ; decrement count
jnz _loop ; if count is not zero jump back
print mem 0:8 ; print final state of segment 1
print mem 0x10:8 ; print final state of segment 2
```



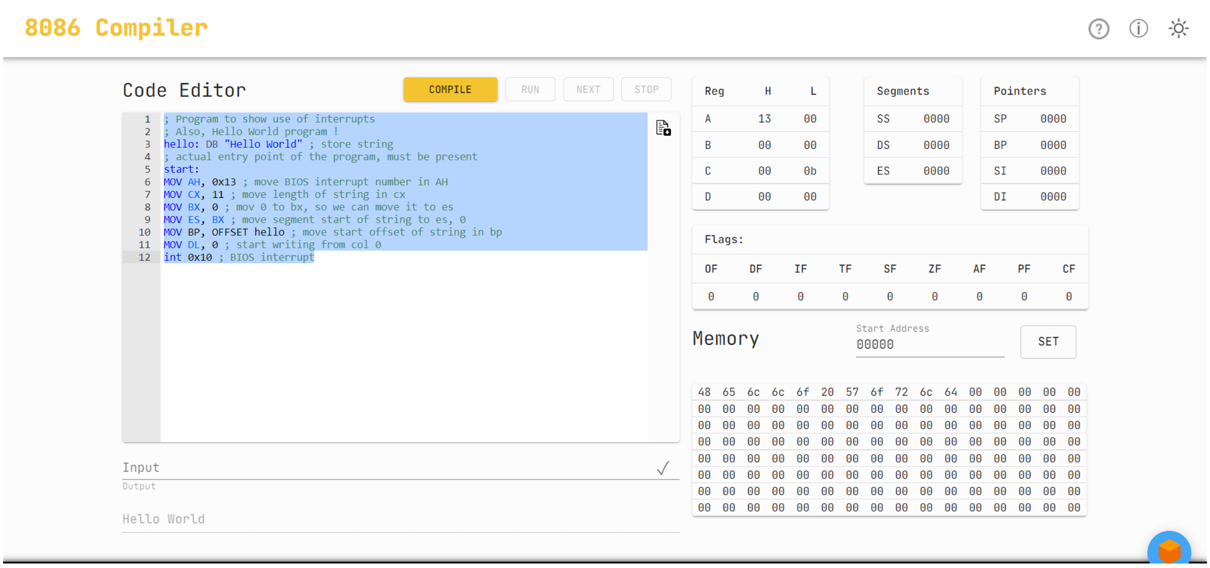

## 3. Program to calculate factorial using looping.

```
; Program to calculate factorial using looping
NUM: DW 0x9 ; calculate factorial of 9
RESULT: DW 0 ; place to store the result
; actual entry point of the program
start:
MOV CX,word NUM ; move number into cx
MOV AX, 0x1 ; initialize accumulator with 1
NOTZEROLOOP: ; label to jump back to
MUL CX ; multiple by the number
DEC CX ; decrement the number
JNZ NOTZEROLOOP ; if not zero jump back
MOV word RESULT,AX ; store the result in memory
print reg ; print registers
```



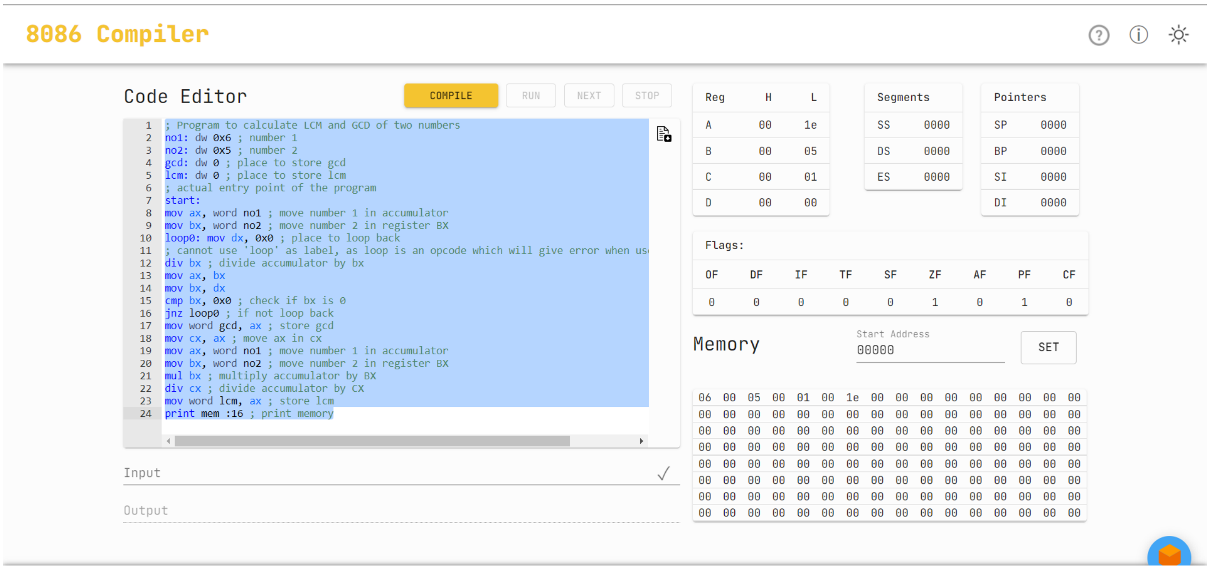

## 4. Program to show use of interrupts.

```
; Program to show use of interrupts
; Also, Hello World program !
hello: DB "Hello World" ; store string
; actual entry point of the program, must be present
start:
MOV AH, 0x13 ; move BIOS interrupt number in AH
MOV CX, 11 ; move length of string in cx
MOV BX, 0 ; mov 0 to bx, so we can move it to es
MOV ES, BX ; move segment start of string to es, 0
MOV BP, OFFSET hello ; move start offset of string in bp
MOV DL, 0 ; start writing from col 0
int 0x10 ; BIOS interrupt
```




**5. Program to calculate LCM and GCD of two numbers.**

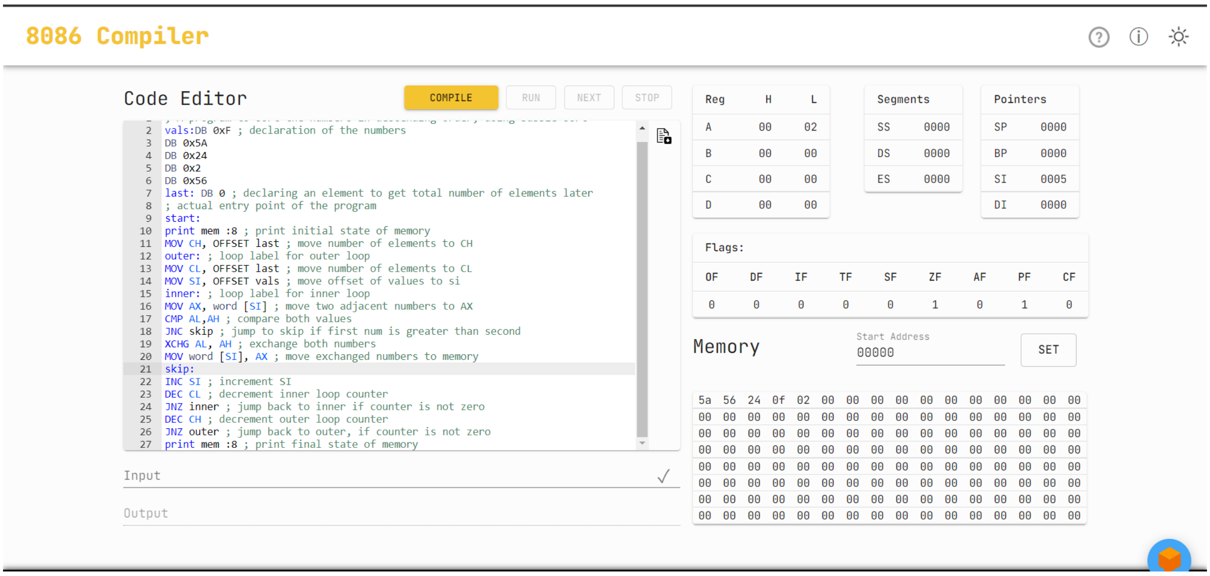
```
; Program to calculate LCM and GCD of two numbers
no1: dw 0x6 ; number 1
no2: dw 0x5 ; number 2
gcd: dw 0 ; place to store gcd
lcm: dw 0 ; place to store lcm
; actual entry point of the program
start:
mov ax, word no1 ; move number 1 in accumulator
mov bx, word no2 ; move number 2 in register BX
loop0: mov dx, 0x0 ; place to loop back
; cannot use 'loop' as label, as loop is an opcode which will give error
when used with jumps
div bx ; divide accumulator by bx
mov ax, bx
mov bx, dx
cmp bx, 0x0 ; check if bx is 0
jnz loop0 ; if not loop back
mov word gcd, ax ; store gcd
mov cx, ax ; move ax in cx
mov ax, word no1 ; move number 1 in accumulator
mov bx, word no2 ; move number 2 in register BX
mul bx ; multiply accumulator by BX
div cx ; divide accumulator by CX
mov word lcm, ax ; store lcm
print mem :16 ; print memory
```




### 6. A program to sort the numbers in descending order, using bubble sort

```
; A program to sort the numbers in descending order, using bubble sort
vals:DB 0xF ; declaration of the numbers
DB 0x5A
DB 0x24
DB 0x2
DB 0x56
last: DB 0 ; declaring an element to get total number of elements later
; actual entry point of the program
start:
print mem :8 ; print initial state of memory
MOV CH, OFFSET last ; move number of elements to CH
outer: ; loop label for outer loop
MOV CL, OFFSET last ; move number of elements to CL
MOV SI, OFFSET vals ; move offset of values to si
inner: ; loop label for inner loop
MOV AX, word [SI] ; move two adjacent numbers to AX
CMP AL,AH ; compare both values
JNC skip ; jump to skip if first num is greater than second
XCHG AL, AH ; exchange both numbers
MOV word [SI], AX ; move exchanged numbers to memory
skip:
INC SI ; increment SI
DEC CL ; decrement inner loop counter
JNZ inner ; jump back to inner if counter is not zero
```

```
DEC CH ; decrement outer loop counter
JNZ outer ; jump back to outer, if counter is not zero
print mem :8 ; print final state of memory
```



# EXPERIMENT - 9

**AIM**: Write Programs using Assembly Language:
1. To implement Macros for calculating Factorial of a number.
2. To study and Implement DOS interrupts. Calculate and display Sum of 2 user entered inputs using DOS interrupt

**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 17/12/21 | 17/12/21 | |

**Theory** :
**Macros** : Writing a macro is another way of ensuring modular programming in assembly language. A macro is a sequence of instructions, assigned by a name and could be used anywhere in the program. In NASM, macros are defined with %macro and %endmacro directives. The macro begins with the %macro directive and ends with the %endmacro directive. The Syntax for macro definition –

```
%macro macro_name number_of_params
<macro body>
%endmacro
```

Where, number_of_params specifies the number parameters, macro_name specifies the name of the macro. The macro is invoked by using the macro name along with the necessary parameters. When you need to use some sequence of instructions many times in a program, you can put those instructions in a macro and use it instead of writing the instructions all the time

Macros are just like procedures, but not really. Macros look like procedures, but they exist only until your code is compiled, after compilation all macros are replaced with real instructions. If you declared a macro and never used it in your code, compiler will simply ignore it. Unlike procedures, macros should be defined above the code that uses it.

The advantage of using Macro is that it avoids the overhead time involved in calling and returning (as in the procedures). Therefore, the execution of Macros is faster as compared to procedures. Another advantage is that there is no need for accessing stack or providing any separate memory to it for storing and returning the address locations while shifting the processor controls in the program.

But it should be noted that every time you call a macro, the assembler of the microprocessor places the entire set of Macro instructions in the mainline program from where the call to Macro is being made. This is known as Macro expansion. Due to this, the program code (which uses Macros) takes more memory space than the code which uses procedures for implementing the same task using the same set of instructions.

**DOS Interrupts**

Interrupt is the method of creating a temporary halt during program execution and allows peripheral devices to access the microprocessor. The microprocessor responds to that interrupt with an ISR (Interrupt Service Routine), which is a short program to instruct the microprocessor on how to handle the interrupt. The following image shows the types of interrupts we have in a 8086 microprocessor –

DOS Interrupt is a Software Interrupt. INT 21H is a DOS interrupt. It is one of the most commonly used interrupts while writing code in 8086 assembly language. To use the DOS interrupt 21H load AH with the desired sub-function. Load other required parameters in other registers, and make a call to INT 21H.

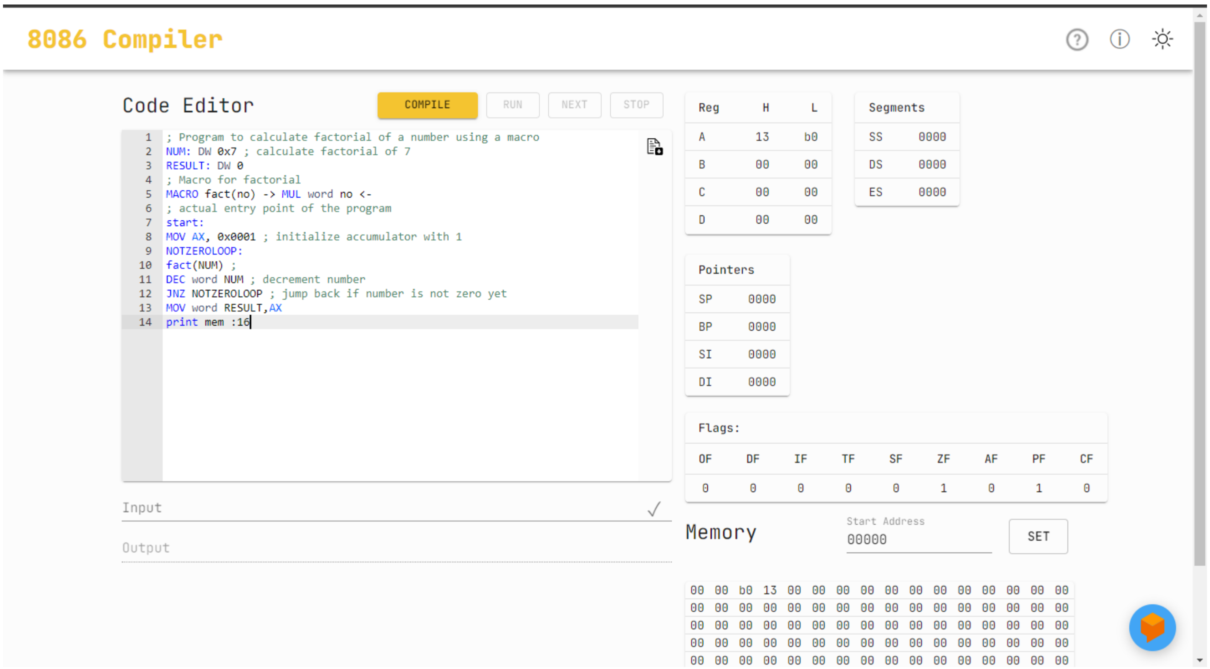
| AH | Description | AH | Description |
|---|---|---|---|
| 01 | Read character from STDIN | 02 | Write character to STDOUT |
| 05 | Write character to printer | 06 | Console Input/Output |
| 07 | Direct char read (STDIN), no echo | 08 | Char read from STDIN, no echo |
| 09 | Write string to STDOUT | 0A | Buffered input |
| 0B | Get STDIN status | 0C | Flush buffer for STDIN |
| 0D | Disk reset | 0E | Select default drive |
| 19 | Get current default drive | 25 | Set interrupt vector |
| 2A | Get system date | 2B | Set system date |
| 2C | Get system time | 2D | Set system time |
| 2E | Set verify flag | 30 | Get DOS version |
| 35 | Get Interrupt vector | | |
| 36 | Get free disk space | 39 | Create subdirectory |

| | | | |
|---|---|---|---|
| 3A | Remove subdirectory | 3B | Set working directory |
| 3C | Create file | 3D | Open file |
| 3E | Close file | 3F | Read file |
| 40 | Write file | 41 | Delete file |
| 42 | Seek file | 43 | Get/Set file attributes |
| 47 | Get current directory | 4C | Exit program |
| 4D | Get return code | 54 | Get verify flag |
| 56 | Rename file | 57 | Get/Set file date |

**CODE:**

**1. Factorial using Macros.**

```
; Program to calculate factorial of a number using a macro
NUM: DW 0x7 ; calculate factorial of 7
RESULT: DW 0
; Macro for factorial
MACRO fact(no) -> MUL word no <-
; actual entry point of the program
start:
MOV AX, 0x0001 ; initialize accumulator with 1
NOTZEROLOOP:
fact(NUM) ;
DEC word NUM ; decrement number
JNZ NOTZEROLOOP ; jump back if number is not zero yet
MOV word RESULT,AX
print mem :16
```




## 2. DOS Interrupt

```
DATA SEGMENT
NUM1 DB ?
NUM2 DB ?
RESULT DB ?
MSG1 DB 10,13,"ENTER FIRST NUMBER TO ADD : $"
MSG2 DB 10,13,"ENTER SECOND NUMBER TO ADD : $"
MSG3 DB 10,13,"RESULT OF ADDITION IS : $"
ENDS
CODE SEGMENT
ASSUME DS:DATA, CS:CODE
START:
MOV AX,DATA
MOV DS,AX
LEA DX,MSG1
MOV AH,9
INT 21H
MOV AH,1
INT 21H
SUB AL,30H
MOV NUM1,AL
LEA DX,MSG2
MOV AH,9
INT 21H
```

```
MOV AH,1
INT 21H
SUB AL,30H
MOV NUM2,AL
ADD AL,NUM1
MOV RESULT,AL
MOV AH,0
AAA
ADD AH,30H
ADD AL,30H
MOV BX,AX
LEA DX,MSG3
MOV AH,9
INT 21H
MOV AH,2
MOV DL,BH
INT 21H
MOV AH,2
MOV DL,BL
INT 21H
MOV AH,4CH
INT 21H
ENDS
END START
```

DOSBox 0.74-3, Cpu speed: 3000 cycles, Frameskip 0, Progra...

```
/z            Display source line with error message
/zi,/zd       Debug info: zi=full, zd=line numbers only
C:\>tasm Addition.asm
Turbo Assembler  Version 2.51  Copyright (c) 1988, 1991 Borland International

Assembling file:   Addition.asm
Error messages:    None
Warning messages:  None
Passes:            1
Remaining memory:  491k


C:\>Addition
Illegal command: Addition.

C:\>tlink Addition
Turbo Link  Version 4.0 Copyright (c) 1991 Borland International
Warning: No stack

C:\>Addition

ENTER FIRST NUMBER TO ADD : 1
ENTER SECOND NUMBER TO ADD : 0
RESULT OF ADDITION IS : 01
C:\>
```

# EXPERIMENT - 10

**Aim:** Write a Program using ALP to Simulate Microcontroller interfacing with 7 segment display using http://vlabs.iitb.ac.in/vlabs-dev/labs/8051-Microcontroller-Lab/labs/exp1/simulation.php. Display your SAP ID using this tool

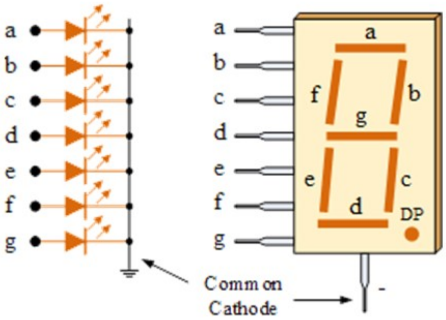
**Submission Sheet**

| SAP ID | Name of Student | Date of Experiment | Date of Submission | Remarks |
|---|---|---|---|---|
| 60004190057 | Junaid Girkar | 3/10/21 | 3/10/21 | |

**THEORY**:
The 7-segment display consists of seven LEDs arranged in a rectangular fashion. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package which is the indication of a decimal point(DP), when two or more 7-segment displays are connected together numbers greater than ten can be displayed.
So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be glowing and others will remain as it is, allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 to 9 on the same 7-segment display.

In the common cathode display, all the cathode connections of the LED segments are joined together to logic “0” or ground. The individual segments are illuminated by application of a “HIGH”, or logic “1” signal via a current limiting resistor to forward bias the individual Anode terminals (a-g).

**Common Cathode 7-segment Display**




| Commom Cathode | | | | | | | |
|---|---|---|---|---|---|---|---|
| Decimal Digit | Individual Segments Illuminated | | | | | | |
| | a | b | c | d | e | f | g |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 1 | | 1 | 1 | | | | |
| 2 | 1 | 1 | | 1 | 1 | | 1 |
| 3 | 1 | 1 | 1 | 1 | | | 1 |
| 4 | | 1 | 1 | | | 1 | 1 |
| 5 | 1 | | 1 | 1 | | 1 | 1 |
| 6 | 1 | | 1 | 1 | 1 | 1 | 1 |
| 7 | 1 | 1 | 1 | | | | |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | 1 | 1 | 1 | 1 | | 1 | 1 |

Common Cathode Decoding Table

| CHAR | A | B | C | D | E | F | G | HEX |
|---|---|---|---|---|---|---|---|---|
| **SAP ID = 60004190057** | | | | | | | | |
| **6** | 1 | | 1 | 1 | 1 | 1 | 1 | 5F |
| **0** | 1 | 1 | 1 | 1 | 1 | 1 | | 7E |
| **4** | | 1 | 1 | | | 1 | 1 | 33 |
| **1** | | 1 | 1 | | | | | 30 |
| **9** | 1 | 1 | 1 | 1 | | 1 | 1 | 7B |
| **5** | 1 | | 1 | 1 | | 1 | 1 | 5B |
| **7** | 1 | 1 | 1 | | | | | 70 |
| **HEXADECIMAL = DF8874769** | | | | | | | | |
| **D** | 1 | 1 | 1 | 1 | 1 | 1 | | 7E |
| **F** | 1 | | | | 1 | 1 | 1 | 47 |
| **8** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7F |

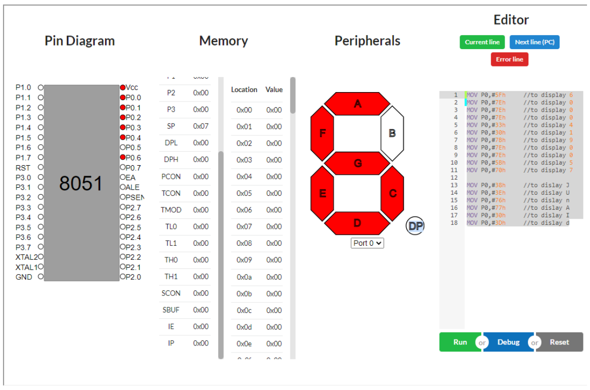
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7** | 1 | 1 | 1 | | | | | 70 |
| **4** | | 1 | 1 | | | 1 | 1 | 33 |
| **6** | 1 | | 1 | 1 | 1 | 1 | 1 | 5F |
| **9** | 1 | 1 | 1 | 1 | | 1 | 1 | 7B |
| **NAME = JUNAID** | | | | | | | | |
| **J** | | 1 | 1 | 1 | | | | 38 |
| **U** | | 1 | 1 | 1 | 1 | 1 | | 3E |
| **N** | 1 | 1 | 1 | | 1 | 1 | | 76 |
| **A** | 1 | 1 | 1 | | 1 | 1 | 1 | 77 |
| **I** | | 1 | 1 | | | | | 30 |
| **D** | | 1 | 1 | 1 | 1 | | 1 | 3D |

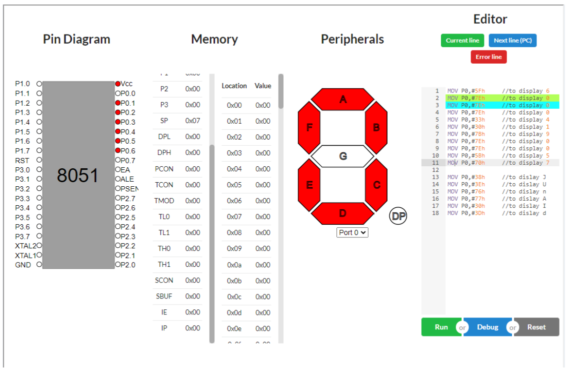
CODE:

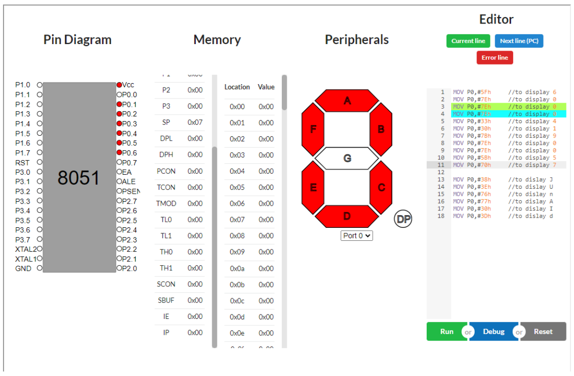
```
MOV P0,#5Fh      //to display 6
MOV P0,#7Eh      //to display 0
MOV P0,#7Eh      //to display 0
MOV P0,#7Eh      //to display 0
MOV P0,#33h      //to display 4
MOV P0,#30h      //to display 1
MOV P0,#7Bh      //to display 9
MOV P0,#7Eh      //to display 0
MOV P0,#7Eh      //to display 0
MOV P0,#5Bh      //to display 5
MOV P0,#70h      //to display 7

MOV P0,#3Dh      //to display d
MOV P0,#47h      //to display F
MOV P0,#7Fh      //to display 8
MOV P0,#7Fh      //to display 8
MOV P0,#70h      //to display 7
MOV P0,#33h      //to display 4
MOV P0,#70h      //to display 7
MOV P0,#5Fh      //to display 6
MOV P0,#7Bh      //to display 9

MOV P0,#38h      //to display J
MOV P0,#3Eh      //to display U
```

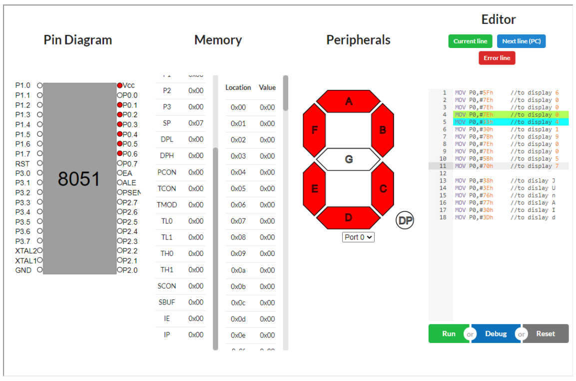
```
MOV P0,#76h      //to display n
MOV P0,#77h      //to display A
MOV P0,#30h      //to display I
MOV P0,#3Dh      //to display d
```

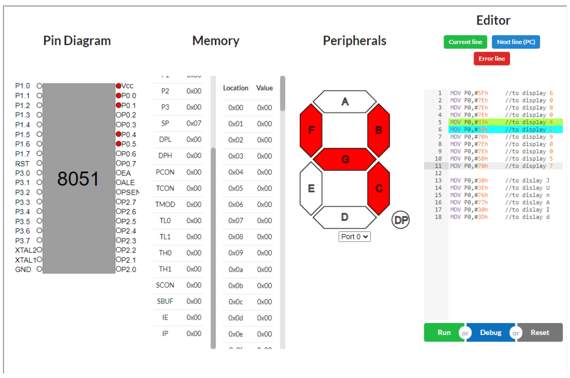
**OUTPUT**:

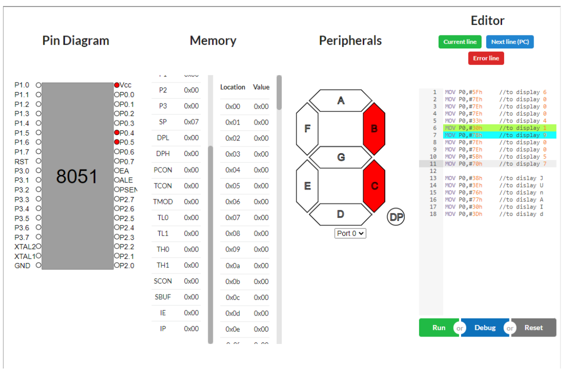


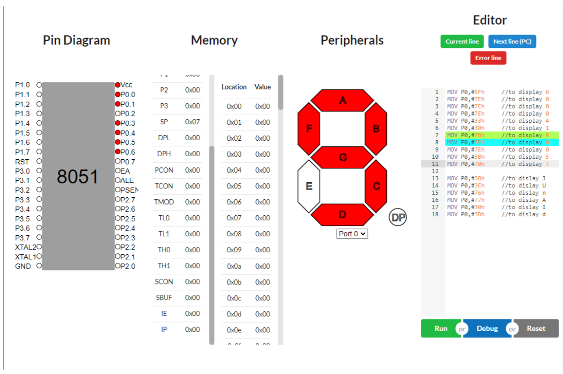

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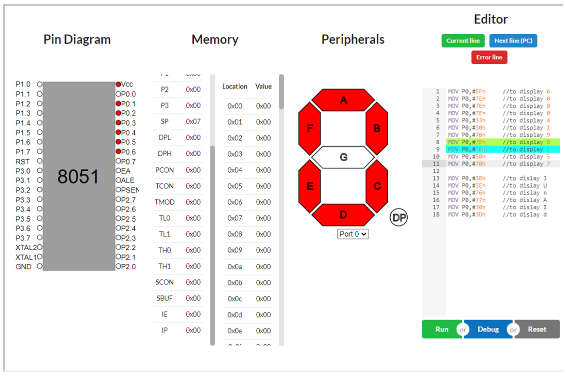
Peripherals
Editor
8051
Run
Debug
Reset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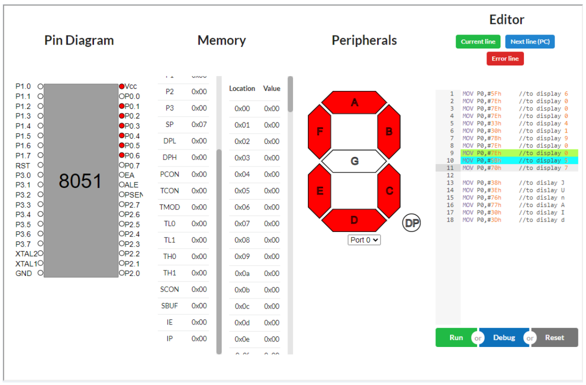
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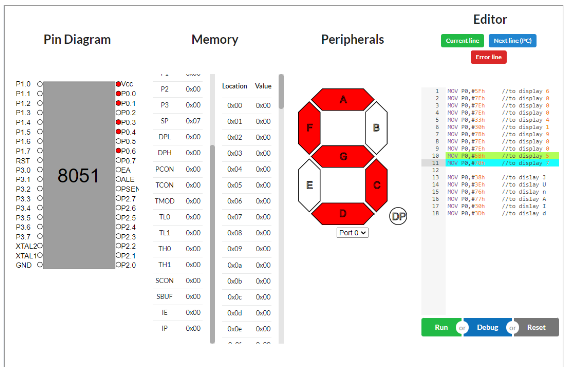
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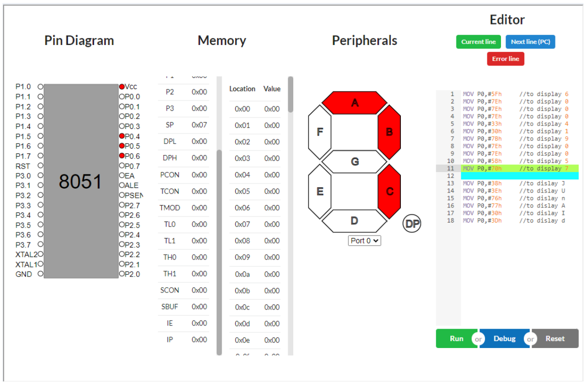
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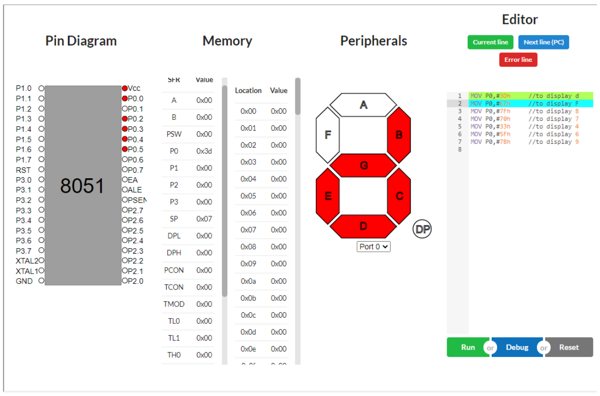
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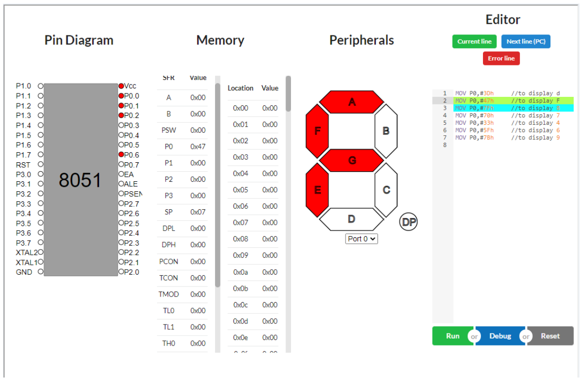
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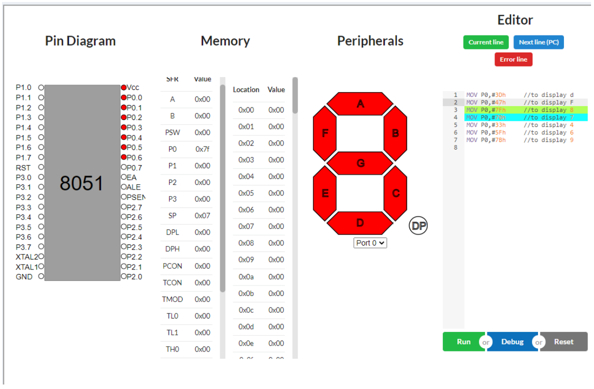
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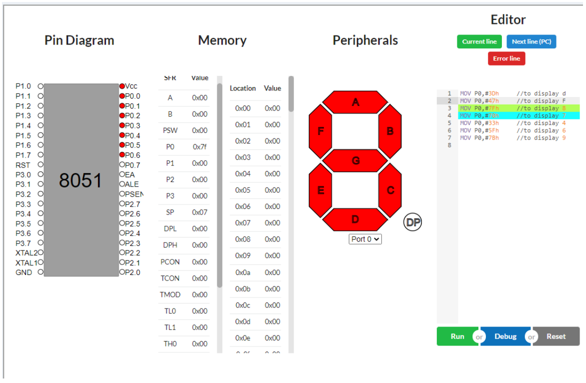
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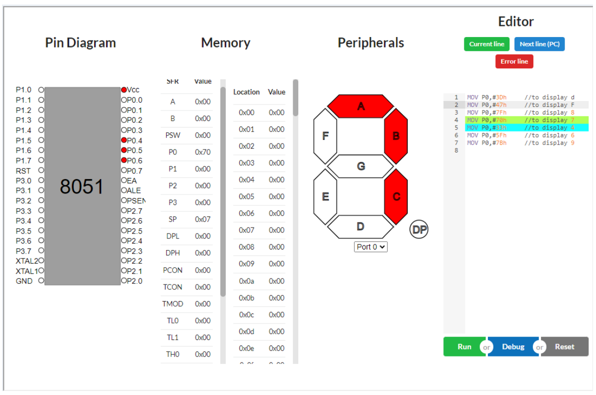
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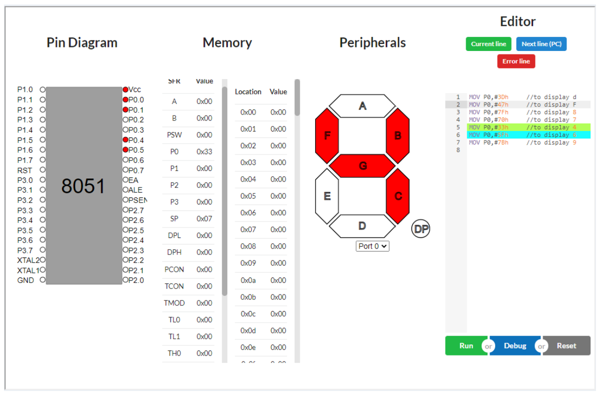
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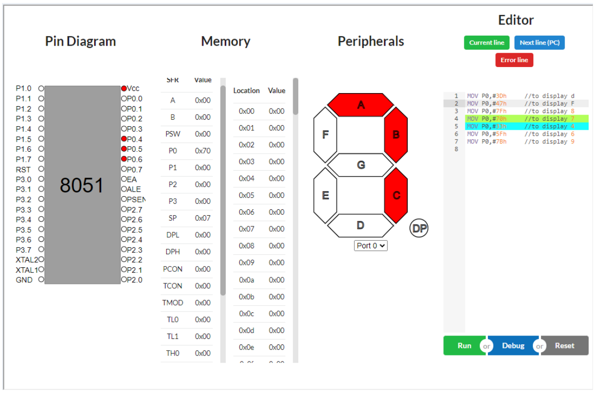
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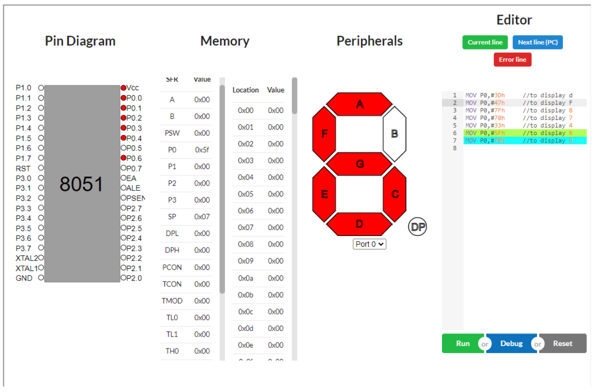
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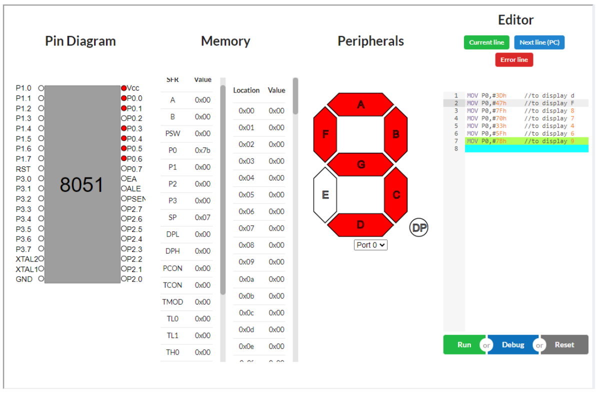
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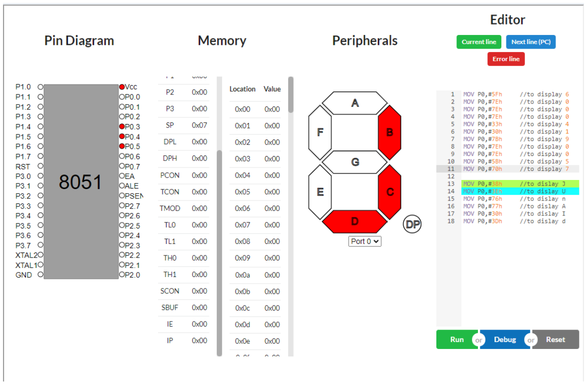


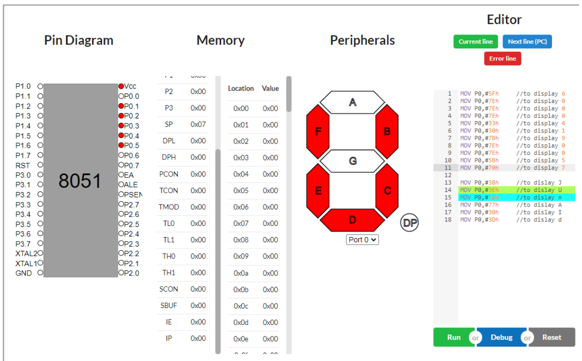


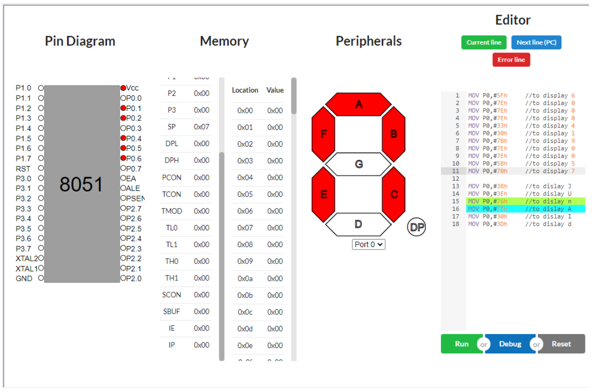


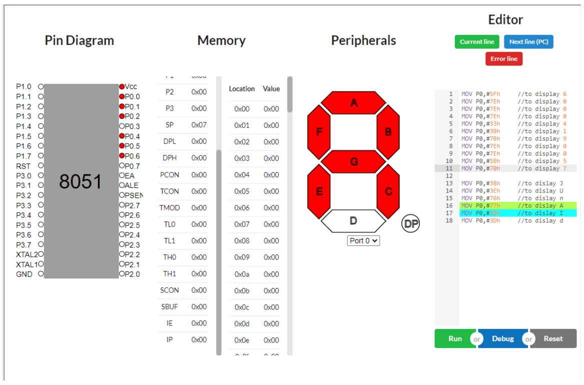


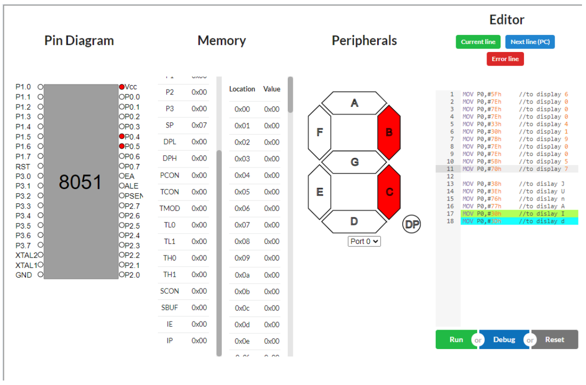


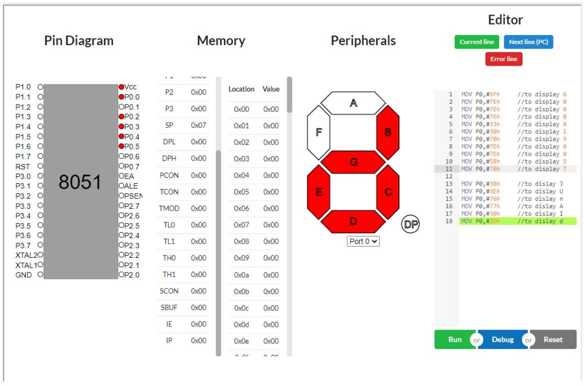


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**CONCLUSION:** We learn about 7 segment display and simulations using the 8051 Microcontroller. We then simulated a few examples by writing the code.

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