Computer Arthematic

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Project#1: CCA

Aim: For an n-bit Carry Completion Adder, write a C program to determine

the relationship between the average delay and operand size (n).

Procedure: Consider the addition of two 4 bit numbers. A= 0 1 1 0 and B= 1 1 0 0. When the completion adder is performed, the following steps take place :

1. Like any other normal addition, the addition takes place from the right most bit. And every addition requires an incoming carry. The right most bits of A and B are 0,0. The incoming carry to these bits is 0. The incoming carry is always 0 for the addition of extreme right most bits. Since the incoming carry is 0, set c0 =1 and c1 =0(acts like a switch). Set all the other incoming carries to other bits as c1=0 and c0=0(switch is neither on nor off i.e not finalized). This entire cycle is "T0" which doesn't have any delay.
2. Now the previous incoming carry for extreme right most bit which set in the last cycle is used by the extreme right most bit to generate a carry out. i.e 0+0+0 which again gives a c0=1 and c1=0(i.e there is 0 carry). The last but one bit i.e the 3rd bit has an incoming carry that is not finalized , therefore the carryout is not finalized as well. For the second bit i.e A=1 and B=1, the incoming carry is not finalzied, yet the carryout is c1=1 (because when the two bits are 1 and 1, no matter what the incoming carry is, the carryout will always be 1). The first bit has an incoming carry which is not finalized, and since we have A=0 and B=1, the carryout is not finalzed. This entire process is cycle "T1"
3. All the carryouts generated in cycle "T1" goes as carry in to the bits of A and B in cycle "T2". Here we try to finalze the bits, which were not finalized in the cycle "T1".
4. This process is continued till all the bits are finalized.
5. This process of addition can be simulated in C language. The code is given below.

Softwares used for simmulation: C and microsoft excell.

C Program:

```
#include<stdio.h>

#include<conio.h>

#include<stdlib.h>

#include<alloc.h>

int k,*a,*b,*c0,*c1,*t0,*t1,i,j,n,s,m,l,td,flag;

long ttd;// variable to store delay

float avgd;// variable to store average delay


void set(){
```

```
  for(j=0;flag==1 && j<=n;j++){


t1[j]=c1[j];
     t0[j]=c0[j];
}// Set function is used to store all the carryout bits in a temporary array, which acts as carry-in bits
}
void bits(int *c0,int *c1,int *t0,int *t1){
//// bit function checks for all conditions possible and generates carry-out bits


for(i=n-1;i>=0;i--){


s=a[i]+b[i];
   if(s==0){
     c0[i]=1;
     c1[i]=0;


   }
   else if(s>1){
     c0[i]=0;
     c1[i]=1;
   }
   else if(s==1){
     if(t0[i+1]==t1[i+1]){
            c0[i]=0;
            c1[i]=0;
     }
else{
            m=s+t1[i+1];
            if(m>1){
```

```
            c0[i]=0;
              c1[i]=1;
            }
            else if(m<=1){
              c0[i]=1;
              c1[i]=0;
            }
     }
   }

  }
}
void main(){

clrscr();
for(n=2;n<=48;n++){
  ttd=0;
  a=(int *)malloc(n*sizeof(int));// creates memory for the array to store the variable no of bits
b=(int *)malloc(n*sizeof(int));
  c1=(int *)malloc((n+1)*sizeof(int));
  c0=(int *)malloc((n+1)*sizeof(int));
  t1=(int *)malloc((n+1)*sizeof(int));
  t0=(int *)malloc((n+1)*sizeof(int));

for(l=0;l<1000;l++){                    //for looping 1000
td=0;
    for(i=0;i<n;i++){
```

```
a[i]=((rand())%2);// random bits will be stored in a[i]
b[i]=((rand())%2);
}


for(i=0;i<n;i++){
t1[i]=0;// initializing all the bits to 0
t0[i]=0;// initializing all the bits to 0
c1[i]=0;
    c0[i]=0;
}
t1[n]=0;// finalizing the carry –in bit, because the incoming carry will always be 0 so t1[n]=0
t0[n]=1;
   c1[n]=0;
   c0[n]=1;

do{
bits(c0,c1,t0,t1);// control goes to the function “bits()” and executes the logic there and returns
flag=0; // flag=0 means the carry outs are finalized
for(k=0;k<=n;k++){
    if(c0[k]==c1[k]){
                    flag=1;// carry outs are not finalized
          set();// calls the function “set()”
}
}

if(flag==0){
td+=2;// calculation of delay for each cycle when bits are finalzied
ttd+=td;// calculation of total delay
```

```
break;
    }
    else{
      td+=2;//calculation of delay when bits are not finalized
}
  }
  while(flag==1);

  }

avgd=(float)ttd/1000;// calculation of average delay
printf("\ntotal delay for %dth bit number is %ld and average delay is %f",n,ttd,avgd);
}
getch();
}
```

Code Explanation:

1. Since we are asked to add two numbers of variable bit size from 2 to 48, I created for loop from n=2 to n<=48.
2. Then I created 6 pointer variabes, a , b , c0, c1,T1,T0. (a and b hold the address of a memory location used to hold n*size of int, which means if the number of bits 2, 4 bytes are allocated. Thus the size allocated depends on the value "n"). Similarly c0 ,c1,T0,T1 hold (n+1)*size of int, which means c0 ,T1,T0, c1 hold the address of memory location that can store (n+1) * size of int. For example if n=2, then c0, c1,T0,T1 will have a memory of 3*2=6 bytes of memory.
3. We are required to take 1000 sets of random inputs to a and b. Therefore I created a for loop for(l=0;l<1000;l++) which iterates 1000 times and in each iteration a[i] and b[i] takes random input which are 1's and 0's. For this to happen, I made another for loop inside, which assigns random inputs to a[i] and b[i] using the random function "rand()%2". This forloop ends here, while the forloop for 1000 iteration still runs.
4. Inside the 1000 iteration for loop, I again created a forloop to initialize all the c0[i], c1[i], T0[i] and T1[i] to 0. This for loop has a condition that i=0;i<n. So all the values less than n will be 0. Outside the forloop c0[n]=1,c1[n]=0,T0[n]=1 and T1[n]=0 will be initilized (since the carry in for last bit is 0).
5. Next I created a do while loop. The body of do{} contains a function called bits(). In this function the main logic lies. For any addition, the operation takes place from the right most bit, so I created a for loop "for(i=n-1;i>=0;i--)", which starts from the last bit. The two last bits are added and stored in an array s[i](note that the addition is not xor, but it's a normal addition), and in this for loop I gave an if condition stating that if s[i]=0, the c0[i]=1 and c1[i]=0, and if s[i]>1, c0[i]=0 and c1[i]=1. If s[i]=1, and T0[i+1] =T1[i+1], then c0[i]=c1[i]=0 i.e carry out is not finalized. (T0 and T1 are temporary bits which hold the carry in bits and c0 and c1 are the carry out bits). If s[i]+ T1[i+1]>1 then c0[i]=0 and c1[i]=1 and if s[i]+T1[i+1]<1 then c0[i]=1 and c1[i]=0. Thus all the posible conditions are chechked in this do loop.
6. To know if the carry out bits are finalized or not, I created a variable flag=0, which means says that the bits are finalized and if flag =1 then they are not finalized.The flag should become 1 when the two bits c1[k] and c0[k] are equal to 0. So I gave that condition in a for loop and if its met flag becomes 1. The do loop executes while flag=1 and doesn't execute when flag=0.
7. Then I call a function calle set(). In set function I store the carry out bits in a temporary array, which act as carry -in bits for the bits in next cycle.
8. For one iteration i.e the 1000 iteration loop the delay for each cycle is calculated as 2d and added for all 1000 iterations. At the end of each iteration the calculated delay "td" is stored total time delay "ttd". For example in the for loop i=0;i<1000; i++, for the first iteration i=0, the delay td is calculated. Say its 6d. Then for the second iteration i=1, the delat td is again calculated and added to the previous delay td and stored in ttd. and this continues for all the iterations. The final value is divided by 1000 to get the average delay for n bits. (Note that n is again varying, so this process repeats for each value of n).

Output of the code:

```
total delay for 2th bit number is 2994 and average delay is 2.994000
total delay for 3th bit number is 3956 and average delay is 3.956000
total delay for 4th bit number is 4814 and average delay is 4.814000
total delay for 5th bit number is 5386 and average delay is 5.386000
total delay for 6th bit number is 5886 and average delay is 5.886000
total delay for 7th bit number is 6292 and average delay is 6.292000
total delay for 8th bit number is 6706 and average delay is 6.706000
total delay for 9th bit number is 7030 and average delay is 7.030000
total delay for 10th bit number is 7462 and average delay is 7.462000
total delay for 11th bit number is 7636 and average delay is 7.636000
total delay for 12th bit number is 7924 and average delay is 7.924000
total delay for 13th bit number is 8172 and average delay is 8.172000
total delay for 14th bit number is 8296 and average delay is 8.296000
total delay for 15th bit number is 8568 and average delay is 8.568000
total delay for 16th bit number is 8634 and average delay is 8.634000
total delay for 17th bit number is 8990 and average delay is 8.990000
total delay for 18th bit number is 9066 and average delay is 9.066000
total delay for 19th bit number is 9214 and average delay is 9.214000
total delay for 20th bit number is 9324 and average delay is 9.324000
total delay for 21th bit number is 9498 and average delay is 9.498000
total delay for 22th bit number is 9710 and average delay is 9.710000
total delay for 23th bit number is 9686 and average delay is 9.686000
total delay for 24th bit number is 9980 and average delay is 9.980000
```

```
total delay for 24th bit number is 9980 and average delay is 9.980000
total delay for 25th bit number is 10134 and average delay is 10.134000
total delay for 26th bit number is 10070 and average delay is 10.070000
total delay for 27th bit number is 10232 and average delay is 10.232000
total delay for 28th bit number is 10396 and average delay is 10.396000
total delay for 29th bit number is 10480 and average delay is 10.480000
total delay for 30th bit number is 10558 and average delay is 10.558000
total delay for 31th bit number is 10642 and average delay is 10.642000
total delay for 32th bit number is 10758 and average delay is 10.758000
total delay for 33th bit number is 10836 and average delay is 10.836000
total delay for 34th bit number is 10962 and average delay is 10.962000
total delay for 35th bit number is 11082 and average delay is 11.082000
total delay for 36th bit number is 11122 and average delay is 11.122000
total delay for 37th bit number is 11196 and average delay is 11.196000
total delay for 38th bit number is 11310 and average delay is 11.310000
total delay for 39th bit number is 11306 and average delay is 11.306000
total delay for 40th bit number is 11362 and average delay is 11.362000
total delay for 41th bit number is 11542 and average delay is 11.542000
total delay for 42th bit number is 11520 and average delay is 11.520000
total delay for 43th bit number is 11578 and average delay is 11.578000
total delay for 44th bit number is 11688 and average delay is 11.688000
total delay for 45th bit number is 11816 and average delay is 11.816000
total delay for 46th bit number is 11802 and average delay is 11.802000
total delay for 47th bit number is 11924 and average delay is 11.924000
total delay for 48th bit number is 12092 and average delay is 12.092000
```

The output of program

Total delay and average delay for bits varying from 2 to 48.

Observation: It can be observed that as the number of bits increases, the average delay increases. Operand size and average delay have a linear relationship. This can be shown clearly in the graph. I used the data and plotted the graph in MicrosoftExcell.

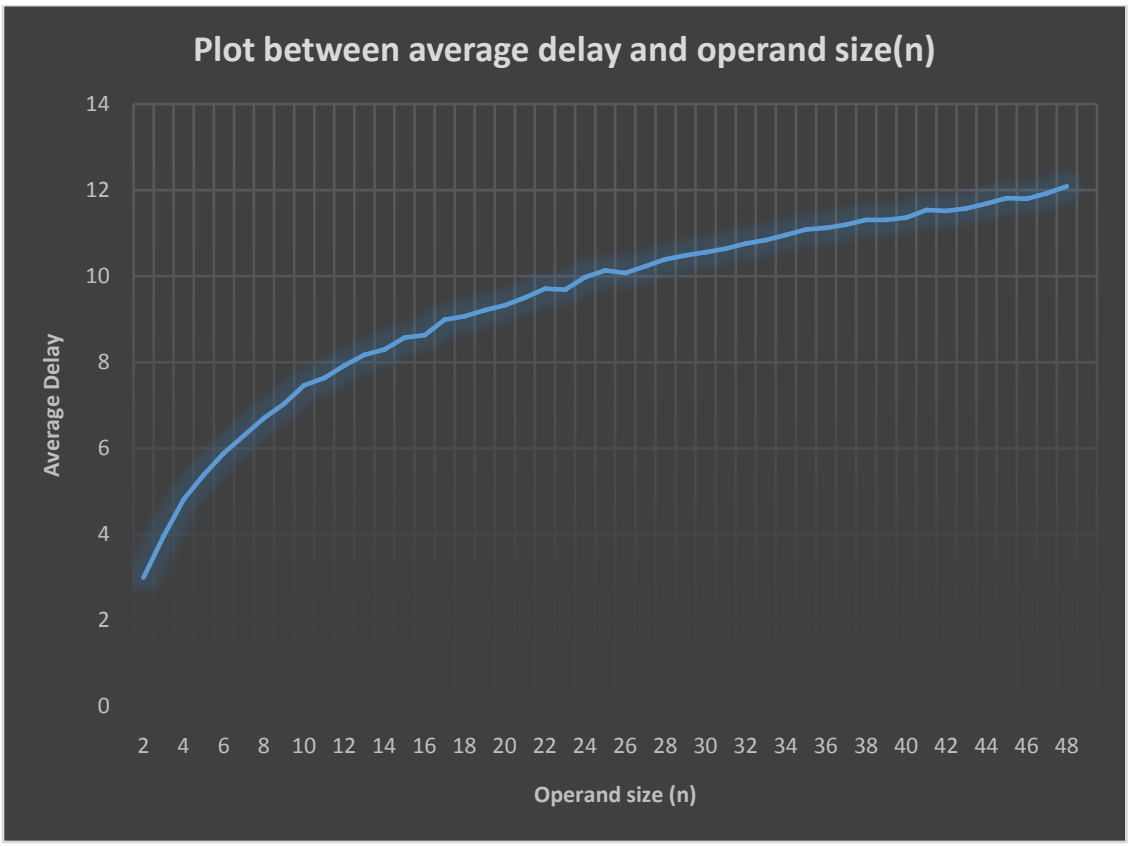


Figure showing the plot between Average Delay and Operand Size (n)

C program for n=24 bit pattern: A= 101001001100101101100101 and B=010101111000010010001011

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

```
#include<alloc.h>
int *sum,*a,*b,*c0,*c1,*t0,*t1,i,j,k,n,s,m,l,t,td,flag; // declaration of variables used in the program
longttd;// variable to store total time delay
floatavgd;// variable to store average delay
void adder(){
for(i=n-1;i>=0;i--){
sum[i]=a[i]^b[i]^c1[i+1];// XOR of a ,b and carry –in, to calculate the sum

}
for(i=0;i<n;i++)
printf("%d ",sum[i]);
}
void set(){
// Set function is used to store the carryout bits in one cycle in a temporary array which acts as a carry in for the  bits in next clock cycle.
for(j=0;flag==1 && j<=n;j++){
t1[j]=c1[j];// As mentioned in the above comments carry out is being stored in temp array
t0[j]=c0[j];
}
}
void bits(){
for(i=n-1;i>=0;i--){
s=a[i]+b[i];
if(s==0){
c0[i]=1;
c1[i]=0;
   }
else if(s>1){
c0[i]=0;
```

```
c1[i]=1;
}
else if(s==1){
if(t0[i+1]==t1[i+1]){
                                        c0[i]=0;
                                        c1[i]=0;
    }
else{
                                        m=s+t1[i+1];
                                        if(m>1){
                                        c0[i]=0;
                                        c1[i]=1;
                                        }
                                        else if(m<=1){
                                        c0[i]=1;
                                        c1[i]=0;
                                        }
    }
   }
  }
}
void main(){

clrscr();
  n=24,t=0;
  a=(int *)malloc(n*sizeof(int));
  b=(int *)malloc(n*sizeof(int));
  c1=(int *)malloc((n+1)*sizeof(int));
  c0=(int *)malloc((n+1)*sizeof(int));
```

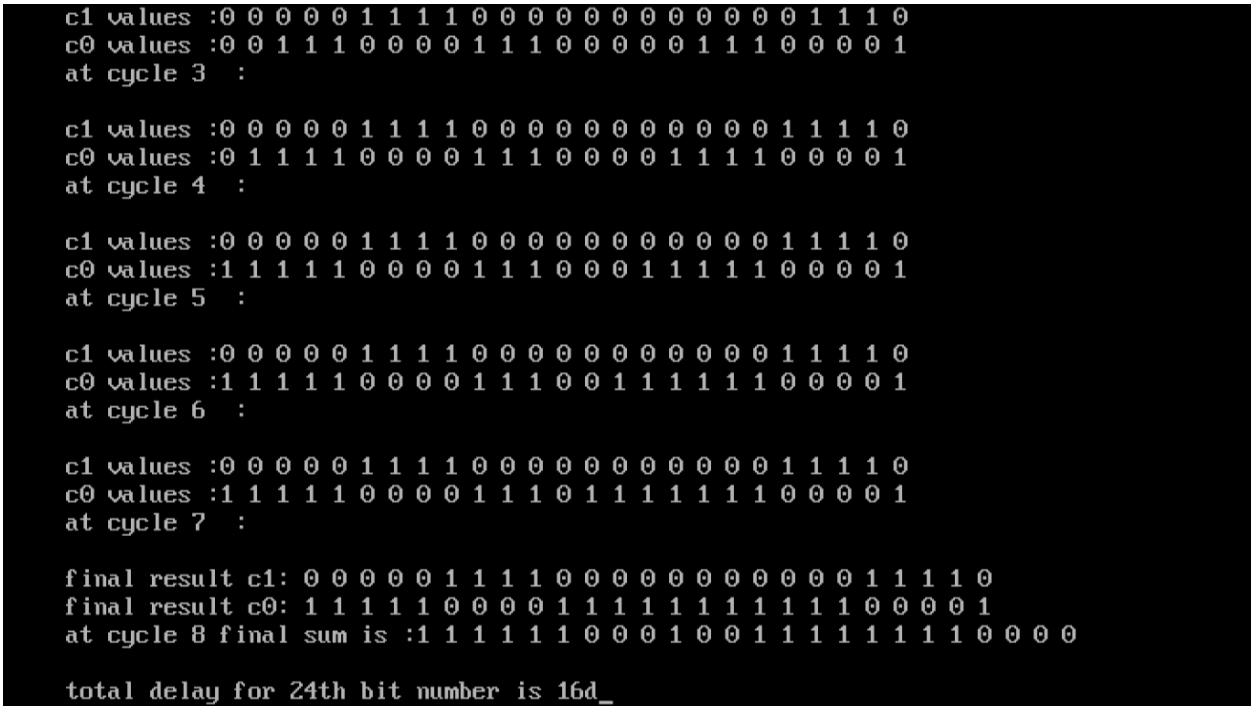
```
  t1=(int *)malloc((n+1)*sizeof(int));
  t0=(int *)malloc((n+1)*sizeof(int));
sum=(int *)malloc((n+1)*sizeof(int));

td=0;
a[0]=1;a[1]=0;a[2]=1;a[3]=0;a[4]=0;a[5]=1;a[6]=0;a[7]=0;a[8]=1;a[9]=1;a[10]=0;a[11]=0;a[12]=1;a[13]=0;
a[14]=1;a[15]=1;a[16]=0;a[17]=1;a[18]=1;a[19]=0;a[20]=0;a[21]=1;a[22]=0;a[23]=1;

b[0]=0;b[1]=1;b[2]=0;b[3]=1;b[4]=0;b[5]=1;b[6]=1;b[7]=1;b[8]=1;b[9]=0;b[10]=0;b[11]=0;b[12]=0;b[13]=
1;b[14]=0;b[15]=0;b[16]=1;b[17]=0;b[18]=0;b[19]=0;b[20]=1;b[21]=0;b[22]=1;b[23]=1;

for(i=0;i<n;i++){
t1[i]=0;
t0[i]=0;
c1[i]=0;
c0[i]=0;
    }
t1[n]=0;
t0[n]=1;
c1[n]=0;
c0[n]=1;
printf("a :");
for(k=0;k<n;k++){
printf("%d ",a[k]);
    }
printf("\nb :");
for(k=0;k<n;k++){
printf("%d ",b[k]);
    }
printf("\n\n");
```

```
do{
printf("\nc1 values :");
for(k=0;k<=n;k++){
printf("%d ",c1[k]);
   }
printf("\nc0 values :");
for(k=0;k<=n;k++){
printf("%d ",c0[k]);
   }
printf("\nat cycle %d  :",t);
printf("\n");
bits();
flag=0;
for(k=0;k<=n;k++){
if(c0[k]==c1[k]){
//printf("value at %d of c0 is %d and c1 is %d\n",j,c0[j],c1[j]);
flag=1;
set();
     }
   }
If(t=3){//If this line and the next line “getch()” is commented, all the 8cycles will be printed, but the only the output that fits the screen will be displayedi.e first 3 cycles will not be displayed because it doesn’t fit on the screen, so  in order to view even the first three cycles, the statements “if(t=3){getch()} should not be commented. If we wish to rest of the 8 cycles comment the statements “if(t=3){getch()}”
Getch();
}
if(flag==0){
t++;
td+=2;
ttd+=td;
```

```
break;
    }
else{
t++;
td+=2;
    }
  }
while(flag==1);

avgd=(float)ttd/1000;
printf("\nfinal result c1: ");
for(i=0;i<=n;i++){
printf("%d ",c1[i]);
  }

printf("\nfinal result c0: ");
for(i=0;i<=n;i++){
printf("%d ",c0[i]);
  }

printf("\nat cycle %d ",t);
printf("final sum is :");
adder();
printf("\n");
printf("\ntotal delay for %dth bit number is %dd",n,td);

getch();
}
```

This program is same as the first program except that the loop n=2 to n=48 and the 1000 iteration loop have been removed and the input to A and B are not given randomly.

Result: The values of sum, Ci(0) and Ci(1) for each cycle are shown as follows.



The output of c program for 24bit patter. It takes 16d to finalize all the carry out bits.

Conclusion:

In each cycle some bits are finalized in parallel and some bits are not finalized. The bits that are finalized in a cycle are given as carry-in to A and B in the next cycle(This can be achieved by using a temporary array t0[i] and t1[i]). This process continues till all the c0 and c1 bits are finalized. It takes 8 cycles to finalize all the bits in c0 and c1, and each cycle takes 2d delay. Therefore the total delay is 2d*8= 16d.

Although in each cycle some bits such as A=0 and B=0 or A=1 and B=1 parallelly generates the carry irrespective of the incoming carry it can be clearly noticed that when the number of bits “n”is more, it takes more cycles to finalize all the bits because when A=1 and B=0 or vice versa the incoming carry is to be finalized to generate a carryout.

Similarly when the number of bits is less, all the bits get finalized in very few cycles.