

## Simplified DES

### 1 Introduction

In this lab we will work through a simplified version of the DES algorithm. The algorithm is not cryptographically secure, but its operations are similar enough to the DES operation to give a better feeling for how it works.

We will proceed by reading the Simplified DES algorithm description in the Stallings section. We will then work through a full example in class.

### 2 Full Example

Let the plaintext be the string 0010 1000. Let the 10 bit key be 1100011110.

#### 2.1 Key Generation

The keys  $k_1$  and  $k_2$  are derived using the functions  $P10$ , Shift, and  $P8$ .

$P10$  is defined as follows:

P10									
3	5	2	7	4	10	1	9	8	6

$P8$  is defined to be as follows:

P8							
6	3	7	4	8	5	10	9

The first key  $k_1$  is therefore equal to:

Bit #	1	2	3	4	5	6	7	8	9	10
$K$	1	1	0	0	0	1	1	1	1	0
$P10(K)$	0	0	1	1	0	0	1	1	1	1
$Shift(P10(K))$	0	1	1	0	0	1	1	1	1	0
$P8(Shift(P10(K)))$	1	1	1	0	1	0	0	1		

The second key  $k_2$  is derived in a similar manner:

Bit #	1	2	3	4	5	6	7	8	9	10
$K$	1	1	0	0	0	1	1	1	1	0
$P10(K)$	0	0	1	1	0	0	1	1	1	1
$Shift^3(P10(K))$	1	0	0	0	1	1	1	0	1	1
$P8(Shift^2(P10(K)))$	1	0	1	0	0	1	1	1		

So we have the two keys  $k_1 = \{1110\ 1001\}$  and  $k_2 = \{1010\ 0111\}$

#### 2.2 Initial and Final Permutation

The plaintext undergoes an initial permutation when it enters the encryption function,  $IP$ . It undergoes a reverse final permutation at the end  $IP^{-1}$ .

The function  $IP$  is defined as follows:

IP							
2	6	3	1	4	8	5	7

The function  $IP^{-1}$  is defined as follows:

$IP^{-1}$							
4	1	3	5	7	2	8	6

Applied to the input, we have the following after the initial permutation:

Bit #	1	2	3	4	5	6	7	8
$P$	0	0	1	0	1	0	0	0
$IP(P)$	0	0	1	0	0	0	1	0

### 2.3 Functions $f_K$ , $SW$ , $K$

- The function  $f_k$  is defined as follows. Let  $P = (L, R)$ , then  $f_K(L, R) = (L \oplus F(R, SK), R)$ .
- The function  $SW$  just switches the two halves of the plaintext, so  $SW(L, R) \rightarrow (R, L)$
- The function  $F(p, k)$  takes a four bit string  $p$  and eight bit key  $k$  and produces a four bit output. It performs the following steps.

1. First it runs an expansion permutation  $E/P$ :

E/P							
4	1	2	3	2	3	4	1

2. Then it XORs the key with the result of the  $E/P$  function
3. Then it substitutes the two halves based on the S-Boxes.

4. Finally, the output from the S-Boxes undergoes the  $P4$  permutation:

P4			
2	4	3	1

Applying the functions, we must perform the following steps:  $IP^{-1} \circ f_{K_2} \circ SW \circ f_{K_1} \circ IP$

1. We have already calculated  $IP(P) = \{0010\ 0010\}$ . Applying the next functions:
2.  $f_{K_1}(L, R) = f_{\{1110\ 1001\}}(0010\ 0010) = (0010 \oplus F(0010, \{1110\ 1001\}), 0010)$
3.  $F(0010, \{1110\ 1001\}) = P4 \circ SBoxes \circ \{1110\ 1001\} \oplus (E/P(0010))$
4. The steps are:

Bit #	1	2	3	4	5	6	7	8
R	0	0	1	0				
E/P(R)	0	0	0	1	0	1	0	0
$k_1$	1	1	1	0	1	0	0	1
$E/P(R) \oplus k_1$	1	1	1	1	1	1	0	1
SBoxes( $E/P(R) \oplus k_1$ )	1	0	0	0				
$P4(SBoxes(E/P(R) \oplus k_1))$	0	0	0	1				

5. The result from  $F$  is therefore 0001
6. Calculating we then have  $f_{k_1}(L, R) = (0010 \oplus 0001, 0010) = (0011, 0010)$
7. So far, then  $L = 0011$  and  $R = 0010$ .  $SW$  just swaps them so  $R = 0011$  and  $L = 0010$ .
8. We now do the calculation of  $f_{k_2}(L, R) = f_{\{1010\ 0111\}}(0010\ 0011) = (0010 \oplus F(0011, \{1010\ 0111\}), 0011)$

9. The steps for  $F$  are as above:

Bit #	1	2	3	4	5	6	7	8
R	0	0	1	1				
E/P(R)	1	0	0	1	0	1	1	0
$k_2$	1	0	1	0	0	1	1	1
E/P(R) $\oplus$ $k_2$	0	0	1	1	0	0	0	1
SBoxes(E/P(R) $\oplus$ $k_2$ )	1	0	1	0				
P4(SBoxes(E/P(R) $\oplus$ $k_2$ ))	0	0	1	1				

10. So now we have the outcome of  $F$  as 0011

11. Calculating we then have  $f_{k_2}(L, R) = (0010 \oplus 0011, 0011) = (0001, 0011)$

12. Last, we perform the  $IP^{-1}$  permutation:

Bit #	1	2	3	4	5	6	7	8
R,L	0	0	0	1	0	0	1	1
$IP^{-1}$ (R,L)	1	0	0	0	1	0	1	0

13. So the final result of the encryption is 1000 1010.