

**Aufgabe 5.8** Gegeben sei der durch die abgebildete zweistufige Seitentabelle beschriebene Adressraum, wobei `0x1000` die Eintrittsadresse für das Page Directory ist. Alle angegebenen Zahlen sind Hexadezimal notiert, ein freies Feld in den letzten drei Spalten bedeutet, dass das entsprechende Bit nicht gesetzt ist. Betrachtet werde eine Menge von Speicherzugriffen aus dem normalen „user mode“ heraus (siehe Tabelle, Bedeutung der Abkürzungen siehe Aufgabe 8). Entscheiden Sie für jeden Speicherzugriff, ob der Zugriff gestattet ist und geben Sie in diesem Fall die physische Adresse an. Bestimmen Sie andernfalls den Grund für auftretende Seitenfehler und beschreiben Sie die Reaktion des Betriebssystems.

# Adressumsetzung x86, 32Bit

- 32-Bit Adressbreite (→ virtuelle Adressen sind immer 32 Bit lang)
- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



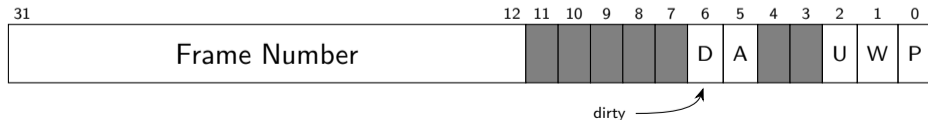
# Adressumsetzung x86, 32Bit

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- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



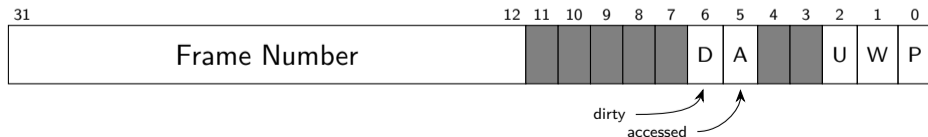
# Adressumsetzung x86, 32Bit

- 32-Bit Adressbreite (→ virtuelle Adressen sind immer 32 Bit lang)
- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



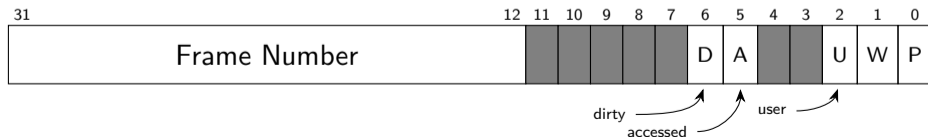
# Adressumsetzung x86, 32Bit

- 32-Bit Adressbreite (→ virtuelle Adressen sind immer 32 Bit lang)
- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



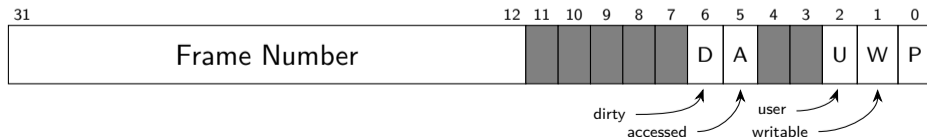
# Adressumsetzung x86, 32Bit

- 32-Bit Adressbreite (→ virtuelle Adressen sind immer 32 Bit lang)
- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



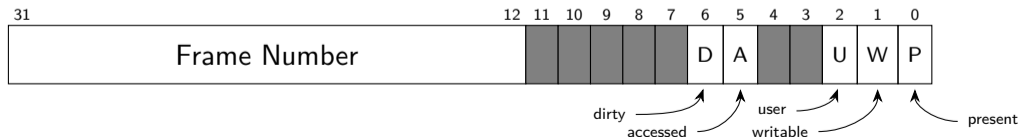
# Adressumsetzung x86, 32Bit

- 32-Bit Adressbreite (→ virtuelle Adressen sind immer 32 Bit lang)
- Größe des virtuellen Adressraums: 4 GiB
- 4 KiB Seitengröße (→ 12 Bit Offset)
- 2-stufige Seitentabellen

## Aufteilung virtuelle Adressen:



## Struktur Seitentabelleneintrag:



# Adressumsetzung x86, 32 Bit

Seitentabelleneinträge verstehen

## Struktur Seitentabelleneintrag:



## Beispiel:

0xBEF025



# Adressumsetzung x86, 32 Bit

Seitentabelleneinträge verstehen

## Struktur Seitentabelleneintrag:



## Beispiel:

0x00BEF025

# Adressumsetzung x86, 32 Bit

Seitentabelleneinträge verstehen

## Struktur Seitentabelleneintrag:



## Beispiel:

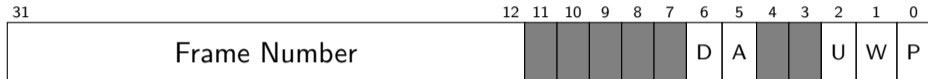
0x00BEF025

FN      Bits

# Adressumsetzung x86, 32 Bit

Seitentabelleneinträge verstehen

## Struktur Seitentabelleneintrag:



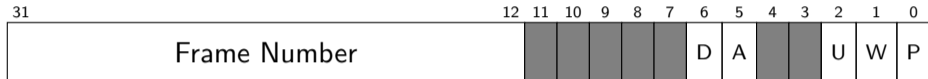
## Beispiel:



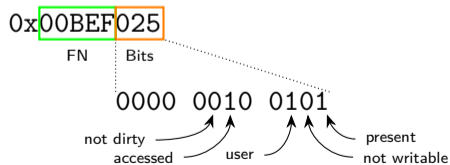
# Adressumsetzung x86, 32 Bit

Seitentabelleneinträge verstehen

## Struktur Seitentabelleneintrag:



## Beispiel:



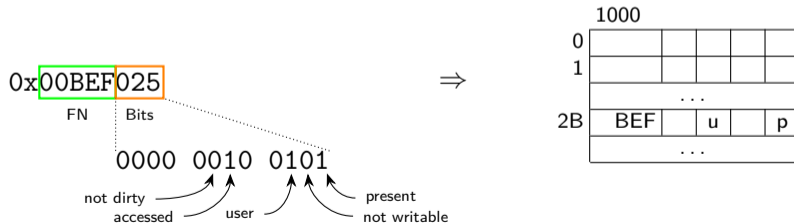
# Adressumsetzung x86, 32 Bit

Seitentableneinträge verstehen

## Struktur Seitentableneintrag:



## Beispiel:



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x1234

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x00001234



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x00001234

PD PT Offset

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

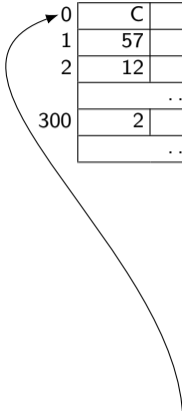
C000

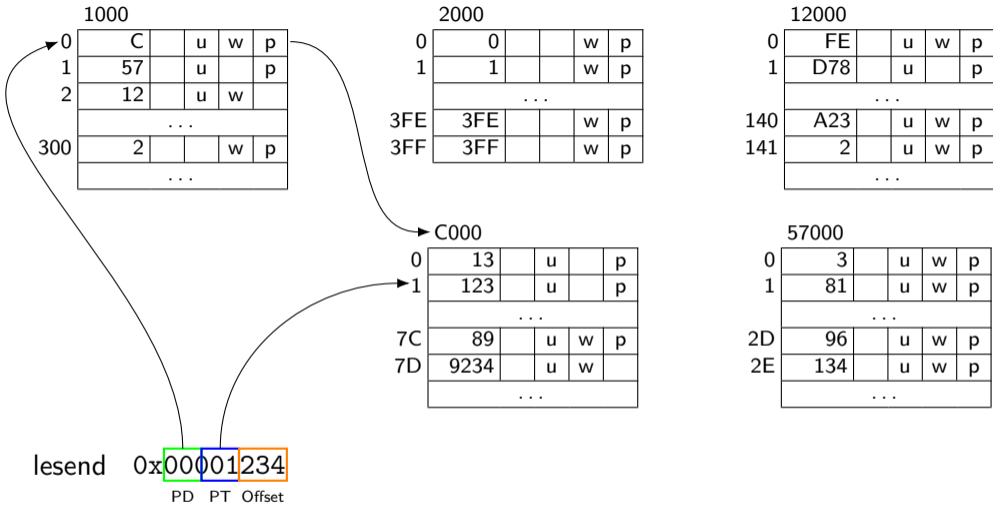
0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

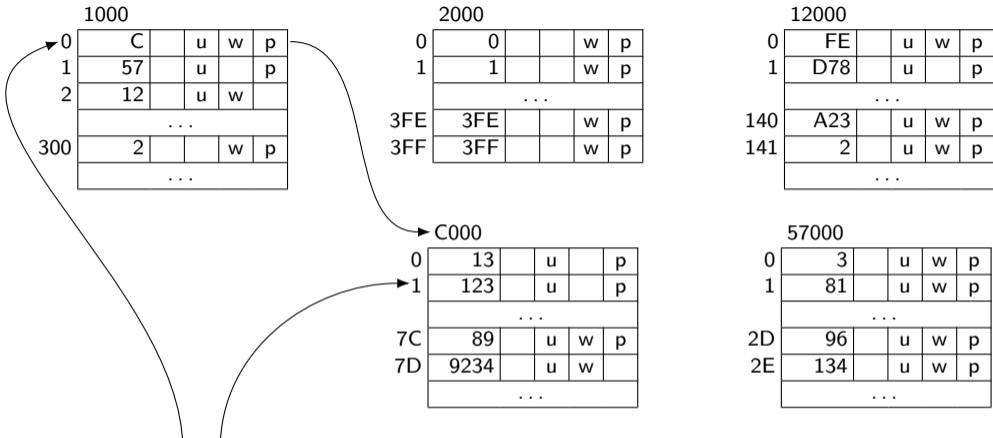
57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x00001234  
 PD PT Offset







lesend 0x00001234 ⇒ 0x123234

00
00
1234

PD
PT
Offset

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x42D8E4

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x0042D8E4

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

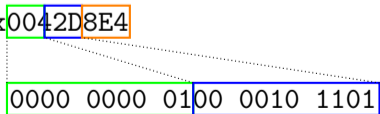
0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x0042D8E4

0000 0000 0100 0010 1101



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x0042D8E4

Offset

0000 0000 0100 0010 1101

PD

PT



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

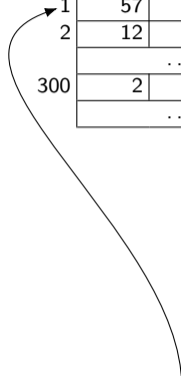
lesend 0x0042D8E4

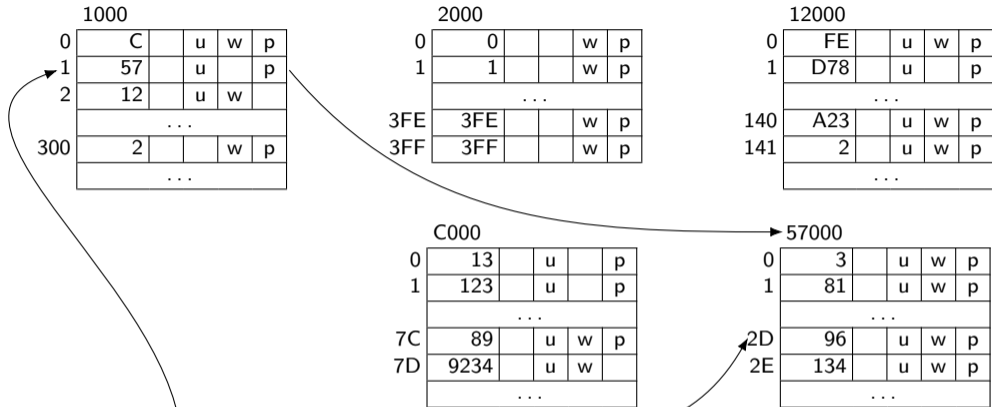
Offset

0000 0000 0100 0010 1101

PD

PT





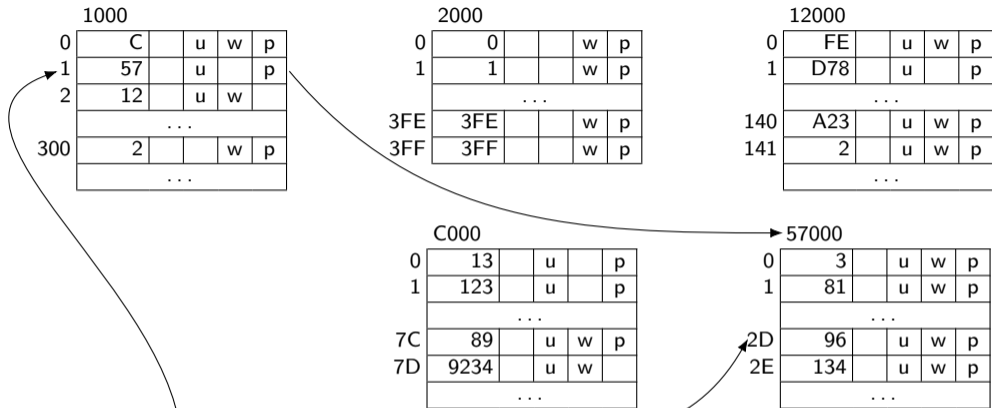
lesend 0x0042D8E4

Offset

0000 0000 0100 0010 1101

PD

PT



lesend 0x0042D8E4 ⇒ 0x968E4

Offset

0000 0000 0100 0010 1101

PD

PT

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x1256

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x00001256

PD PT Offset

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

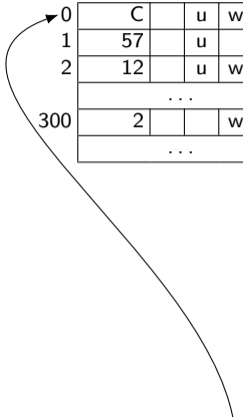
0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

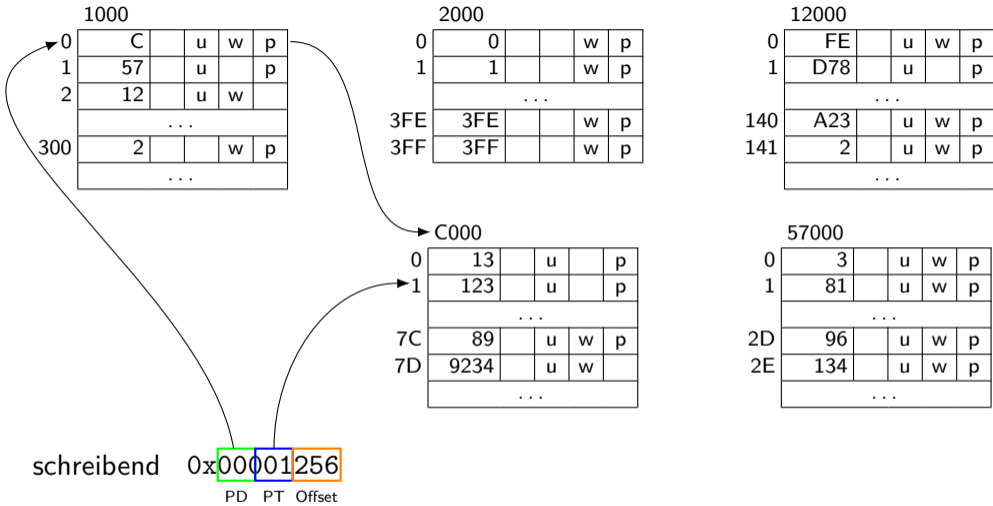
0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

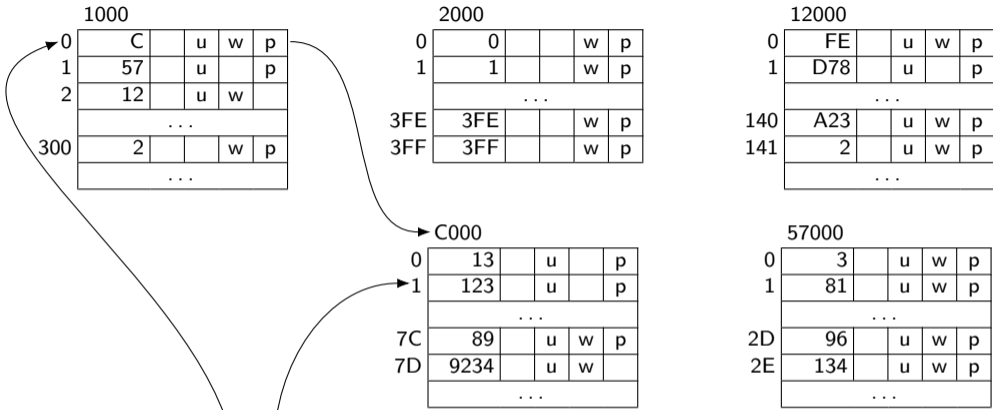
57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					



schreibend 0x00001256  
 PD PT Offset





schreibend 0x00001256 ⇒ PF (page ro)

00
00
1256

PD
PT
Offset



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x400985

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x00400985

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

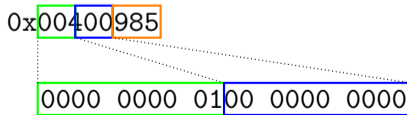
C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x00400985

Offset

0000 0000 0100 0000 0000

PD

PT

1000

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2	12		u	w	
...					
300	2			w	p
...					

2000

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1	1			w	p
...					
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3FF	3FF			w	p

12000

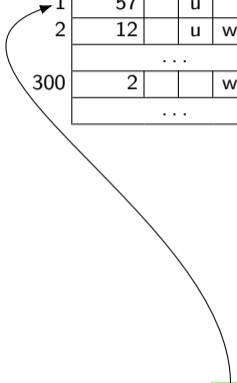
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1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

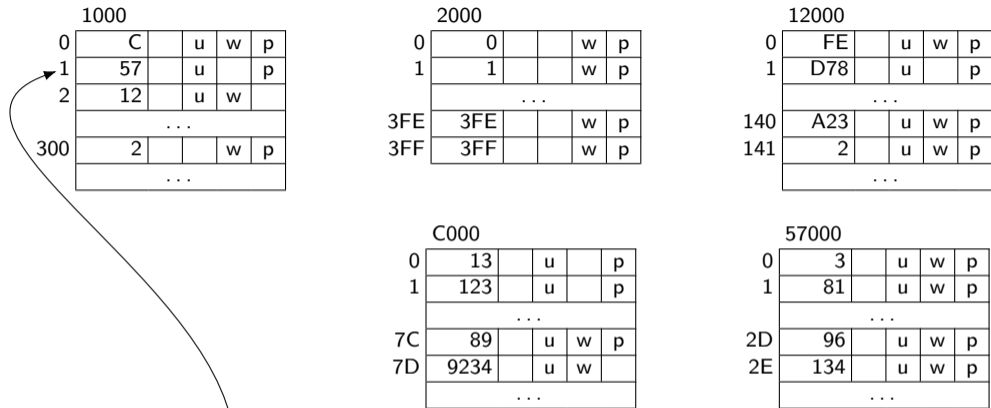
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...					
2D	96		u	w	p
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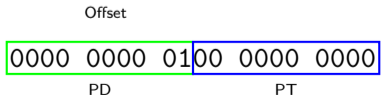


schreibend 0x00400985  
Offset

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PD PT



schreibend 0x00400985 ⇒ PF (page table ro)



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2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x7DF87

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300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
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...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x0007DF87

PD PT Offset



1000

0	C		u	w	p
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300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
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141	2		u	w	p
...					

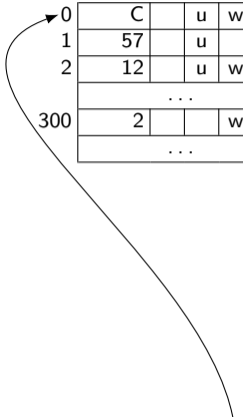
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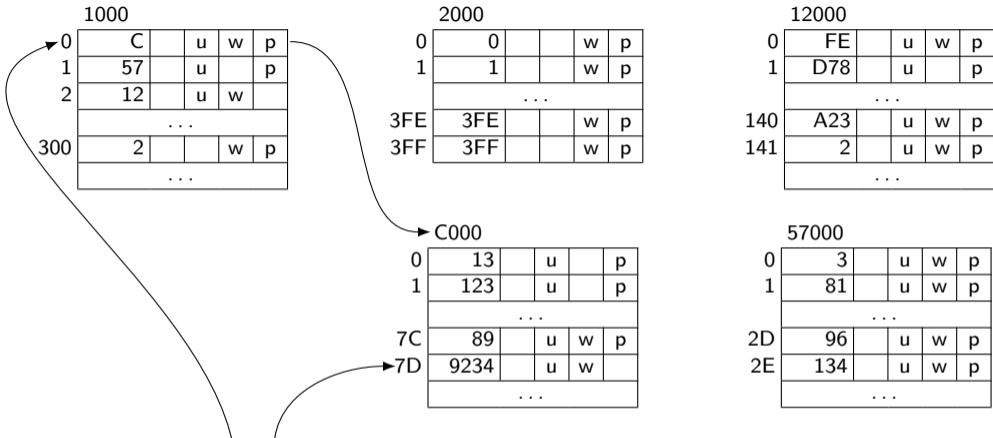
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...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

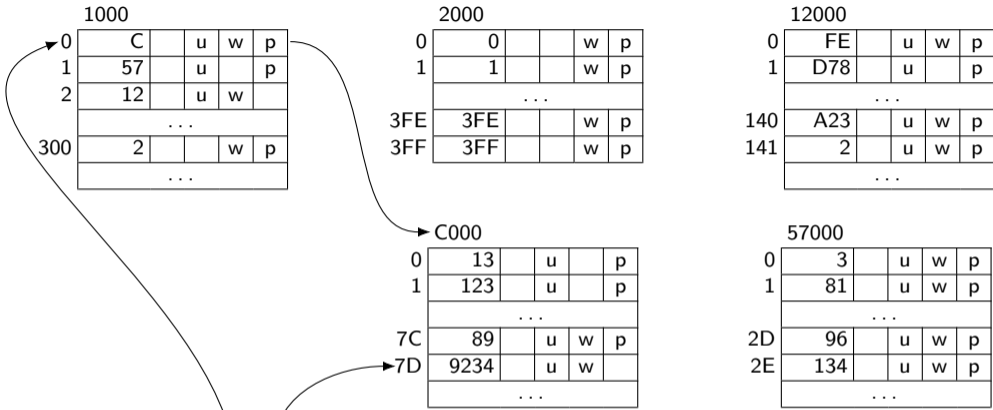
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...					
2D	96		u	w	p
2E	134		u	w	p
...					

schreibend 0x0007DF87  
 PD PT Offset





schreibend 0x0007DF87  
 PD PT Offset



schreibend 0x0007DF87 ⇒ PF (page not present)

000
7D
F87

PD PT Offset

1000

0	C		u	w	p
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2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
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lesend 0x940AFE

1000

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2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x00940AFE

1000

0	C		u	w	p
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2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0x00940AFE

1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

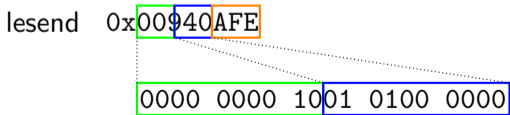
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...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					



1000

0	C		u	w	p
1	57		u		p
2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
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2E	134		u	w	p
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lesend 0x00940AFE

Offset

0000 0000 1001 0100 0000

PD

PT



1000

0	C		u	w	p
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300	2			w	p
...					

2000

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1	1			w	p
...					
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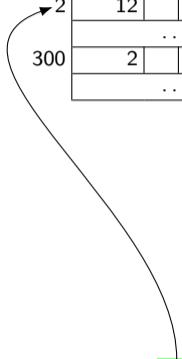
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...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					



lesend 0x00940AFE  
Offset

0000 0000 1001 0100 0000  
PD PT

1000

0	C		u	w	p
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2	12		u	w	
...					
300	2			w	p
...					

2000

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1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

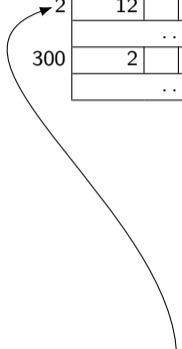
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141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					



lesend 0x00940AFE ⇒ PF (page table not present)

Offset

0000 0000 1001 0100 0000

PD

PT

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0	C		u	w	p
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300	2			w	p
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2000

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...					
3FE	3FE			w	p
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12000

0	FE		u	w	p
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C000

0	13		u		p
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...					

57000

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lesend 0xC03FEB81

1000

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2000

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12000

0	FE		u	w	p
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...					

C000

0	13		u		p
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...					

57000

0	3		u	w	p
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lesend 0xC03FEB81

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3FF	3FF			w	p

12000

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C000

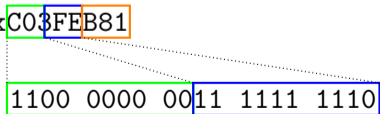
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7D	9234		u	w	
...					

57000

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1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0xC03FEB81

1100 0000 0011 1111 1110



1000

0	C		u	w	p
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2	12		u	w	
...					
300	2			w	p
...					

2000

0	0			w	p
1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
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7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
1	81		u	w	p
...					
2D	96		u	w	p
2E	134		u	w	p
...					

lesend 0xC03FEB81

Offset

1100 0000 0011 1111 1110

PD

PT

1000

0	C		u	w	p
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300	2			w	p
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2000

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1	1			w	p
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3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
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141	2		u	w	p
...					

C000

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1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

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2D	96		u	w	p
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lesend 0xC03FEB81

Offset

11 0000 0000 11 1111 1110

PD

PT

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12000

0	FE		u	w	p
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...					
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141	2		u	w	p
...					

C000

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...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

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...					
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...					

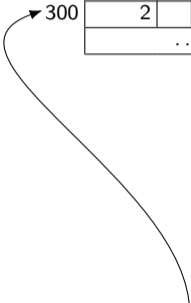
lesend 0xC03FEB81

Offset

11 0000 0000 11 1111 1110

PD

PT





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300	2			w	p
...					

2000

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1	1			w	p
...					
3FE	3FE			w	p
3FF	3FF			w	p

12000

0	FE		u	w	p
1	D78		u		p
...					
140	A23		u	w	p
141	2		u	w	p
...					

C000

0	13		u		p
1	123		u		p
...					
7C	89		u	w	p
7D	9234		u	w	
...					

57000

0	3		u	w	p
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lesend 0xC03FEB81 ⇒ PF (page table not user accessible)

Offset

11 0000 0000 11 1111 1110

PD

PT

