

# Demo

CSR to CVR

# Matrix

- $15 * 15$
- $\text{nnz} = 51$

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6
	10		9								8			
				7										
			1				5			9				7
2			5		8	4	4				1			
		8												1
				6			7					6		
			5			10		9						
								4		6				11

# Matrix

Thread\_0  
nnz = 26

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

Thread\_1  
nnz = 25

	10		9								8			
				7										
			1				5			9				7
2			5		8	4	4				1			
		8												1
				6			7					6		
			5			10		9						
								4		6				11

# Thread\_0, initialize

val	1	1	2	3	5	8	1	3	2	1	3	4	5	5	8	9
col_idx	1	3	4	6	12	0	3	4	7	8	10	14	1	5	10	11

  

row_ptr	0	5	12	15	17
---------	---	---	----	----	----

lane	val		col_idx		tail	tracker		
						valid	rowID	count
0	-	-	-	-	-	0	0	5
1	-	-	-	-	-	5	1	7
2	-	-	-	-	-	12	2	3
3	-	-	-	-	-	15	4	2

rowID = row

valid =  
row\_ptr[row]

count =  
row\_ptr[row+1]  
- row\_ptr[row]

# Convert

val	1	1	2	3	5	8	1	3	2	1	3	4	5	5	8	9
col_idx	1	3	4	6	12	0	3	4	7	8	10	14	1	5	10	11
row_ptr	0	5	12	15	17											

Diagram illustrating the conversion of row\_ptr values to the corresponding elements in the val and col\_idx arrays. The row\_ptr array contains values 0, 5, 12, 15, and 17. Red arrows indicate the mapping: row\_ptr 0 points to val[1] and col\_idx[1]; row\_ptr 5 points to val[6] and col\_idx[6]; row\_ptr 12 points to val[14] and col\_idx[14]; row\_ptr 15 points to val[10] and col\_idx[10]; and row\_ptr 17 points to val[11] and col\_idx[11].

lane	val		col_idx		tail	tracker		
						valid	rowID	count
0	1	-	1	-	-	0	0	5
1	8	-	0	-	-	5	1	7
2	5	-	1	-	-	12	2	3
3	9	-	11	-	-	15	4	2

# Convert

val	1	1	2	3	5	8	1	3	2	1	3	4	5	5	8	9
col_idx	1	3	4	6	12	0	3	4	7	8	10	14	1	5	10	11

  

row_ptr	0	5	12	15	17
---------	---	---	----	----	----

Diagram illustrating the mapping from row\_ptr to col\_idx and val arrays:

- row\_ptr 0 maps to col\_idx 1 and val 1.
- row\_ptr 5 maps to col\_idx 3 and val 1.
- row\_ptr 12 maps to col\_idx 4 and val 2.
- row\_ptr 15 maps to col\_idx 6 and val 3.
- row\_ptr 17 maps to col\_idx 12 and val 8.

lane	val		col_idx		tail	tracker		
						valid	rowID	count
0	1	-	1	-	-	1	0	4
1	8	-	0	-	-	6	1	6
2	5	-	1	-	-	13	2	2
3	9	-	11	-	-	16	4	1

valid++

count--

# Convert

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

[illegible]

# Convert

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val			col_idx			tail	tracker		
								valID	rowID	count
0	1	-	-	1	-	-	-	1	0	4
1	8	-	-	0	-	-	-	6	1	6
2	5	-	-	1	-	-	-	13	2	2
3	9	-	-	11	-	-	-	16	4	1



# Trigger recording

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val			col_idx			tail	tracker		
								valID	rowID	count
0	1	1	-	1	3	-	-	2	0	3
1	8	1	-	0	3	-	-	7	1	5
2	5	5	-	1	5	-	-	14	2	1
3	9	1	-	11	12	-	-	17	4	0

# Record

lane	val			col_idx			tail	tracker		
	$i = 0$	$i = 1$						valid	rowID	count
0	1	1	-	1	3	-	-	2	0	3
1	8	1	-	0	3	-	-	7	1	5
2	5	5	-	1	5	-	-	14	2	1
lane = 3	3	9	1	-	11	12	-	17	4	0

$pos = i * n\_lanes + lane$

$wb = rowID$

rec	pos	7	-
	wb	4	-

# Feed

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val			col_idx			tail	tracker		
								valID	rowID	count
0	1	1	-	1	3	-	-	2	0	3
1	8	1	-	0	3	-	-	7	1	5
2	5	5	-	1	5	-	-	14	2	1
3	9	1	-	11	12	-	-	17	5	4

# Convert

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val			col_idx			tail	tracker		
								valID	rowID	count
0	1	1	-	1	3	-	-	2	0	3
1	8	1	-	0	3	-	-	7	1	5
2	5	5	-	1	5	-	-	14	2	1
3	9	1	-	11	12	-	-	17	5	4

Convert

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker									
									valID	rowID	count							
0	1	1	-	-	-	-	-	2	0	3								
1	8	1	-	-	-	-	-	7	1	5								
2	5	5	-	-	-	-	-	14	2	1								
3	9	1	-	-	-	-	-	17	5	4								
	col_idx							<div>rec</div>										
	1	3	-	-	-	-	-							pos	7	-	-	-
	0	3	-	-	-	-	-							wb	4	-	-	-
	1	5	-	-	-	-	-							pos	-	-	-	-
	11	12	-	-	-	-	-							wb	-	-	-	-

# Record

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker				
									valID	rowID	count		
0	1	1	2	-	-	-	-	-	3	0	2		
1	8	1	3	-	-	-	-	-	8	1	4		
2	5	5	8	-	-	-	-	-	15	2	0		
3	9	1	4	-	-	-	-	-	18	5	3		
	col_idx												
	1	3	4	-	-	-	-	rec	pos	7	10	-	-
	0	3	4	-	-	-	-		wb	4	2	-	-
	1	5	10	-	-	-	-		pos	-	-	-	-
	11	12	1	-	-	-	-		wb	-	-	-	-

# Feed

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	-	-	-	-	-	3	0	2
1	8	1	3	-	-	-	-	-	8	1	4
2	5	5	8	-	-	-	-	-	21	6	5
3	9	1	4	-	-	-	-	-	18	5	3

col_idx						
1	3	4	-	-	-	-
0	3	4	-	-	-	-
1	5	10	-	-	-	-
11	12	1	-	-	-	-

rec	pos	7	10	-	-
	wb	4	2	-	-
	pos	-	-	-	-
	wb	-	-	-	-

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	-	-	-	-	-	3	0	2
1	8	1	3	-	-	-	-	-	8	1	4
2	5	5	8	-	-	-	-	-	21	6	5
3	9	1	4	-	-	-	-	-	18	5	3

Last row



lane	val							tail	tracker		
									valid	rowID	count
0	1	1	2	-	-	-	-	0	3	0	2
1	8	1	3	-	-	-	-	1	8	1	4
2	5	5	8	-	-	-	-	6	21	2	5
3	9	1	4	-	-	-	-	5	18	3	3

tail[] = rowID[]

rowID[] = lane

Feeding will be replaced by  
stealing since then.

Convert

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker									
									valID	rowID	count							
0	1	1	2	-	-	-	-	0	3	0	2							
1	8	1	3	-	-	-	-	1	8	1	4							
2	5	5	8	-	-	-	-	6	21	2	5							
3	9	1	4	-	-	-	-	5	18	3	3							
	col_idx							<div>rec</div>										
	1	3	4	-	-	-	-							pos	7	10	-	-
	0	3	4	-	-	-	-							wb	4	2	-	-
	1	5	10	-	-	-	-							pos	-	-	-	-
	11	12	1	-	-	-	-							wb	-	-	-	-

# Convert

	1		1	2		3					5		
8			1	3			2	1		3			4
	5				5					8			
											9	1	
	4	4				2							3
3							3				7		7 6

lane	val							tail	tracker								
									valID	rowID	count						
0	1	1	2	3	-	-	-	0	4	0	1						
1	8	1	3	2	-	-	-	1	9	1	3						
2	5	5	8	3	-	-	-	6	22	2	4						
3	9	1	4	4	-	-	-	5	19	3	2						
	col_idx							<div>rec</div>									
	1	3	4	6	-	-	-						pos	7	10	-	-
	0	3	4	7	-	-	-						wb	4	2	-	-
	1	5	10	0	-	-	-						pos	-	-	-	-
	11	12	1	2	-	-	-						wb	-	-	-	-

# Record

	1		1	2		3					5		
8			1	3			2	1		3			4
	5				5					8			
											9	1	
	4	4				2						3	
3							3				7		7 6

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	3	5	-	-	0	5	0	0
1	8	1	3	2	1	-	-	1	10	1	2
2	5	5	8	3	3	-	-	6	23	2	3
3	9	1	4	4	2	-	-	5	20	3	1

col_idx						
1	3	4	6	12	-	-
0	3	4	7	8	-	-
1	5	10	0	7	-	-
11	12	1	2	6	-	-

lr_rec = 16					
rec	pos	7	10	16	-
	wb	4	2	0	-
	pos	-	-	-	-
	wb	-	-	-	-

# Steal

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	3	5	-	-	0	5	0	0
1	8	1	3	2	1	-	-	1	10	1	2
2	5	5	8	3	3	-	-	6	23	2	3
3	9	1	4	4	2	-	-	5	20	3	1

$$\text{average} = (2 + 3 + 1 + n\_lanes - 1) / n\_lanes = 2$$

# Steal

lane	val							tail	tracker		
									valid	rowID	count
0	1	1	2	3	5	-	-	0	5	0	0
1	8	1	3	2	1	-	-	1	10	1	2
2	5	5	8	3	3	-	-	6	23	2	3
3	9	1	4	4	2	-	-	5	20	3	1

average = 2

count[2] > average  
candidate = 2

# Steal

lane	val							tail	tracker		
									validID	rowID	count
0	1	1	2	3	5	-	-	0	23	2	2
1	8	1	3	2	1	-	-	1	10	1	2
2	5	5	8	3	3	-	-	6	25	2	1
3	9	1	4	4	2	-	-	5	20	3	1

average = 2

count[2] > average

candidate = 2

valid = valid[candidate]

rowID = candidate

count = average

valid[candidate] += average

count[candidate] -= average

# Convert

lr\_rec = 16

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker									
									valID	rowID	count							
0	1	1	2	3	5	-	-	0	23	2	2							
1	8	1	3	2	1	-	-	1	10	1	2							
2	5	5	8	3	3	-	-	6	25	2	1							
3	9	1	4	4	2	-	-	5	20	3	1							
	col_idx							<div>rec</div>										
	1	3	4	6	12	-	-							pos	7	10	16	-
	0	3	4	7	8	-	-							wb	4	2	0	-
	1	5	10	0	7	-	-							pos	-	-	-	-
	11	12	1	2	6	-	-							wb	-	-	-	-



# Record

lr\_rec = 16

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker																							
									valID	rowID	count																					
0	1	1	2	3	5	7	-	0	24	2	1																					
1	8	1	3	2	1	3	-	1	11	1	1																					
2	5	5	8	3	3	6	-	6	26	2	0																					
3	9	1	4	4	2	3	-	5	21	3	0																					
	col_idx							<div>rec</div> <table><tr><td>pos</td><td>7</td><td>10</td><td>16</td><td>22</td></tr><tr><td>wb</td><td>4</td><td>2</td><td>0</td><td>2</td></tr><tr><td>pos</td><td>23</td><td>-</td><td>-</td><td>-</td></tr><tr><td>wb</td><td>3</td><td>-</td><td>-</td><td>-</td></tr></table>					pos	7	10	16	22	wb	4	2	0	2	pos	23	-	-	-	wb	3	-	-	-
	pos	7	10	16	22																											
	wb	4	2	0	2																											
	pos	23	-	-	-																											
	wb	3	-	-	-																											
1	3	4	6	12	11	-																										
0	3	4	7	8	10	-																										
1	5	10	0	7	14	-																										
11	12	1	2	6	13	-																										

# Steal(the last round)

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	3	5	7	-	0	24	2	1
1	8	1	3	2	1	3	-	1	11	1	1
2	5	5	8	3	3	6	-	6	26	2	0
3	9	1	4	4	2	3	-	5	21	3	0

average =  $(1 + 1 + n\_lanes - 1) / n\_lanes = 1$   
count[] <= average

# Steal(the last round)

lane	val							tail	tracker		
									valID	rowID	count
0	1	1	2	3	5	7	-	0	24	2	1
1	8	1	3	2	1	3	-	1	11	1	1
2	5	5	8	3	3	6	-	6	-1	2	1
3	9	1	4	4	2	3	-	5	-1	3	1

average = 1  
count[] <= average

valID = -1  
count = 1  
(padding)

# Convert

lr\_rec = 16

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

lane	val							tail	tracker								
									valID	rowID	count						
0	1	1	2	3	5	7	-	0	24	2	1						
1	8	1	3	2	1	3	-	1	11	1	1						
2	5	5	8	3	3	6	-	6	-1	2	1						
3	9	1	4	4	2	3	-	5	-1	3	1						
	col_idx							rec									
	1	3	4	6	12	11	-						pos	7	10	16	22
	0	3	4	7	8	10	-						wb	4	2	0	2
	1	5	10	0	7	14	-						pos	23	-	-	-
	11	12	1	2	6	13	-						wb	3	-	-	-

# Record

lr\_rec = 16

	1		1	2		3					5		
8			1	3			2	1		3			4
	5				5					8			
											9	1	
	4	4				2						3	
3							3				7		7 6

lane	val							tail	tracker			
									valID	rowID	count	
0	1	1	2	3	5	7	7	0	25	2	0	
1	8	1	3	2	1	3	4	1	12	1	0	
2	5	5	8	3	3	6	0	6	0	2	0	
3	9	1	4	4	2	3	0	5	0	3	0	
	col_idx							<div>rec<div>pos7101622wb4202pos232425- wb321-</div></div>				
	1	3	4	6	12	11	13					
	0	3	4	7	8	10	14					
	1	5	10	0	7	14	14					
	11	12	1	2	6	13	14					

Thread\_0

	1		1	2		3						5		
8			1	3			2	1		3				4
	5				5					8				
											9	1		
	4	4				2							3	
3							3				7		7	6

CVR

lane	val							tail	col_idx						
0	1	1	2	3	5	7	7	0	1	3	4	6	12	11	13
1	8	1	3	2	1	3	4	1	0	3	4	7	8	10	14
2	5	5	8	3	3	6	0	6	1	5	10	0	7	14	14
3	9	1	4	4	2	3	0	5	11	12	1	2	6	13	14

rec	pos	7	10	16	22	23	24	25
	wb	4	2	0	2	3	2	1

lr\_rec = 16