CEE 551 - Traffic Science

Topic: Traffic Signal Control (1)

Xingmin Wang

Department of Civil and Environmental Engineering
University of Michigan
Email: xingminw@umich.edu

Content

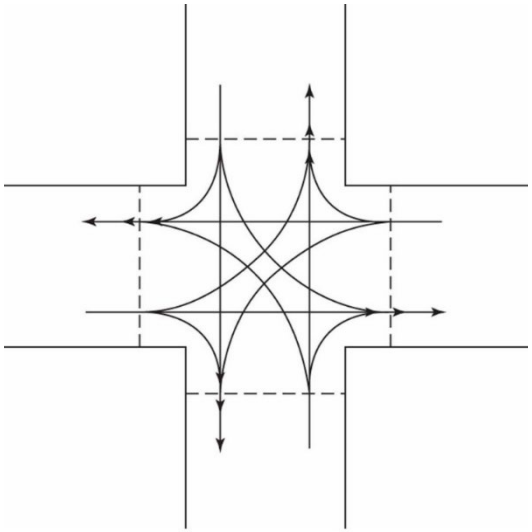
- Part I: Traffic Signal Control Basics
  - Basics of Traffic Signal Control
  - Traffic Signal Parameters
  - Signal Timing Design
  - Delay and Level of Service Analysis
  - Coordination
- Part II: Advanced Traffic Signal Control

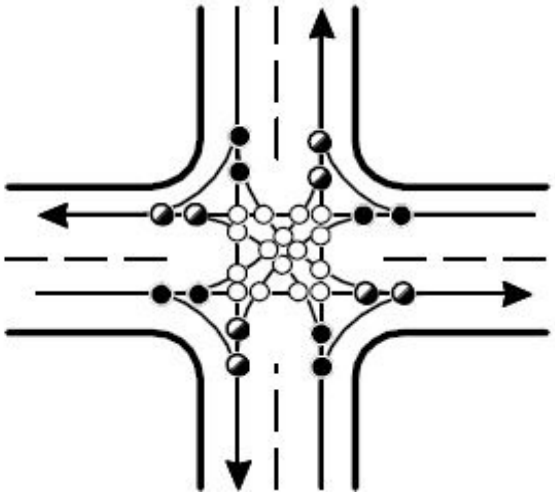
Outline

- Traffic signal control basics
  - Conflict points, intersection geometry, etc.
- **Fixed-time control**
  - Ring-and-barrier diagram
  - Phase sequence
- **Actuated control**
  - Control logic
  - Detector layout
- Real-world example (optional)

Intersection Control

- Typical Conflicts at a Four-Leg Intersection





8	Diverging
8 (12)	Merging
16	Crossing

- Movement: a certain moving direction (4 through movements + 4 left-turn movements + 4 right-turn movements)
- Each left/through has 4 crossing + 2 merging
- Each right-turn has 2 merging

Intersection Control

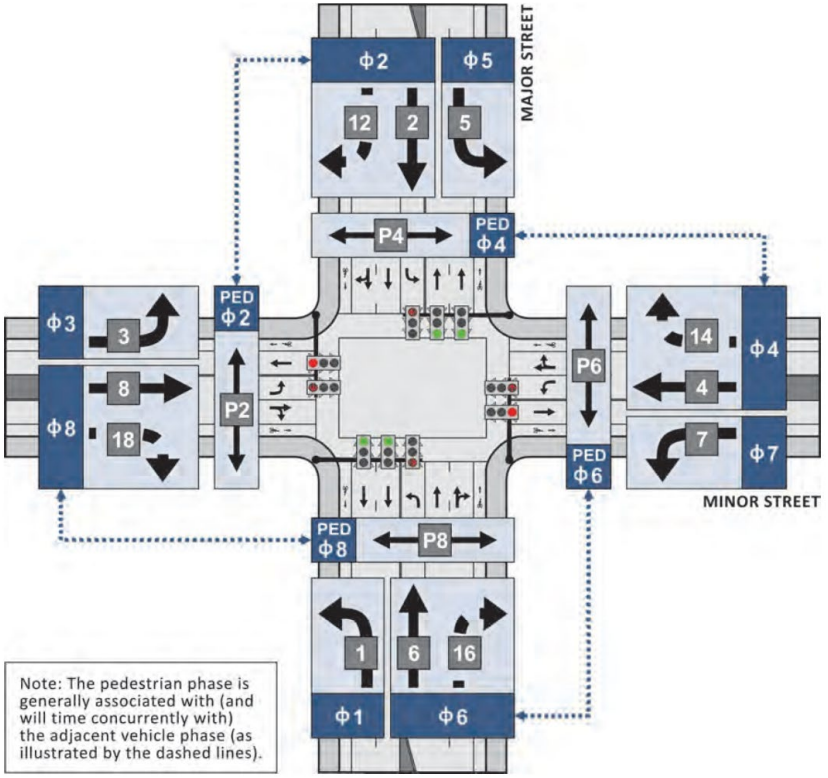
- Intersection is the major bottleneck in urban traffic networks
- Intersection Control
  - Safety (avoid conflict) & efficiency
  - Spatialo-temporal resource allocation
- Level of Intersection Control
  - Level 1: Basic rule (no control sign/device): the driver on the left should yield driver on the right
  - Level 2: YIELD, STOP signs and roundabout
  - Level 3: Traffic Signal Control
    - Advantages: More efficient under heavier traffic demands, reduce right-angle collisions, provide progression along multiple intersections
    - Disadvantages: Excessive delay under low demand level, increases in rear-end collisions

Signal Control Types

- **Fixed-time control**: fixed parameter, fixed duration
- **Actuated control**: fixed parameter, flexible duration
  - Semi-actuated: detectors on minor approach
  - Fully actuated: detectors on each approach
- Adaptive control: flexible parameters, flexible duration

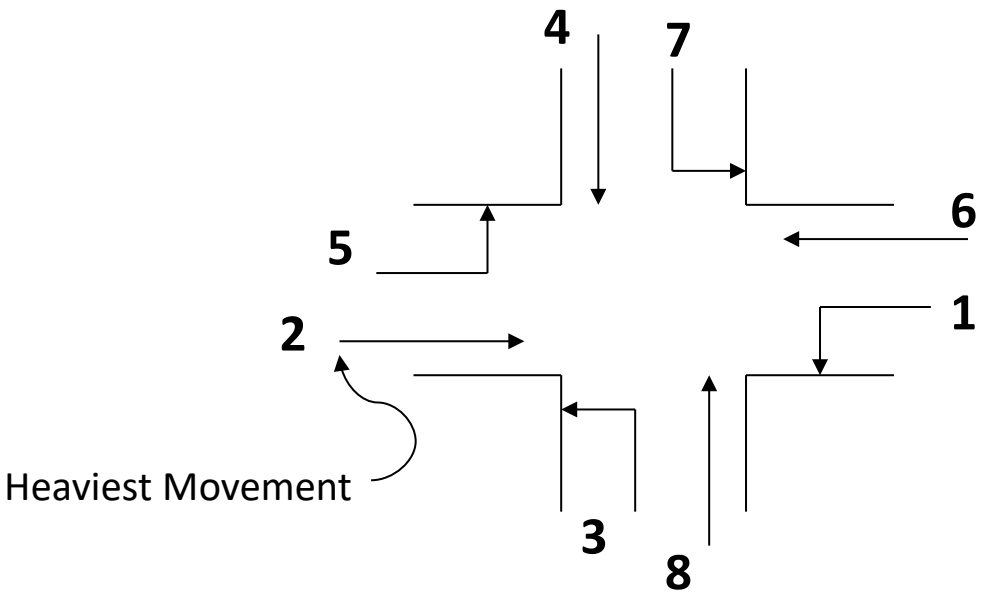
Phase and Movement

- Movement: a certain moving direction (4 through, 4 left-turn, and 4 right-turn)
- Phase: a timing process or a channel within the controller (Green + Yellow + Red)
- A phase might control multiple movements
- Many people use them as the same concept (I think they should be distinguished clearly)

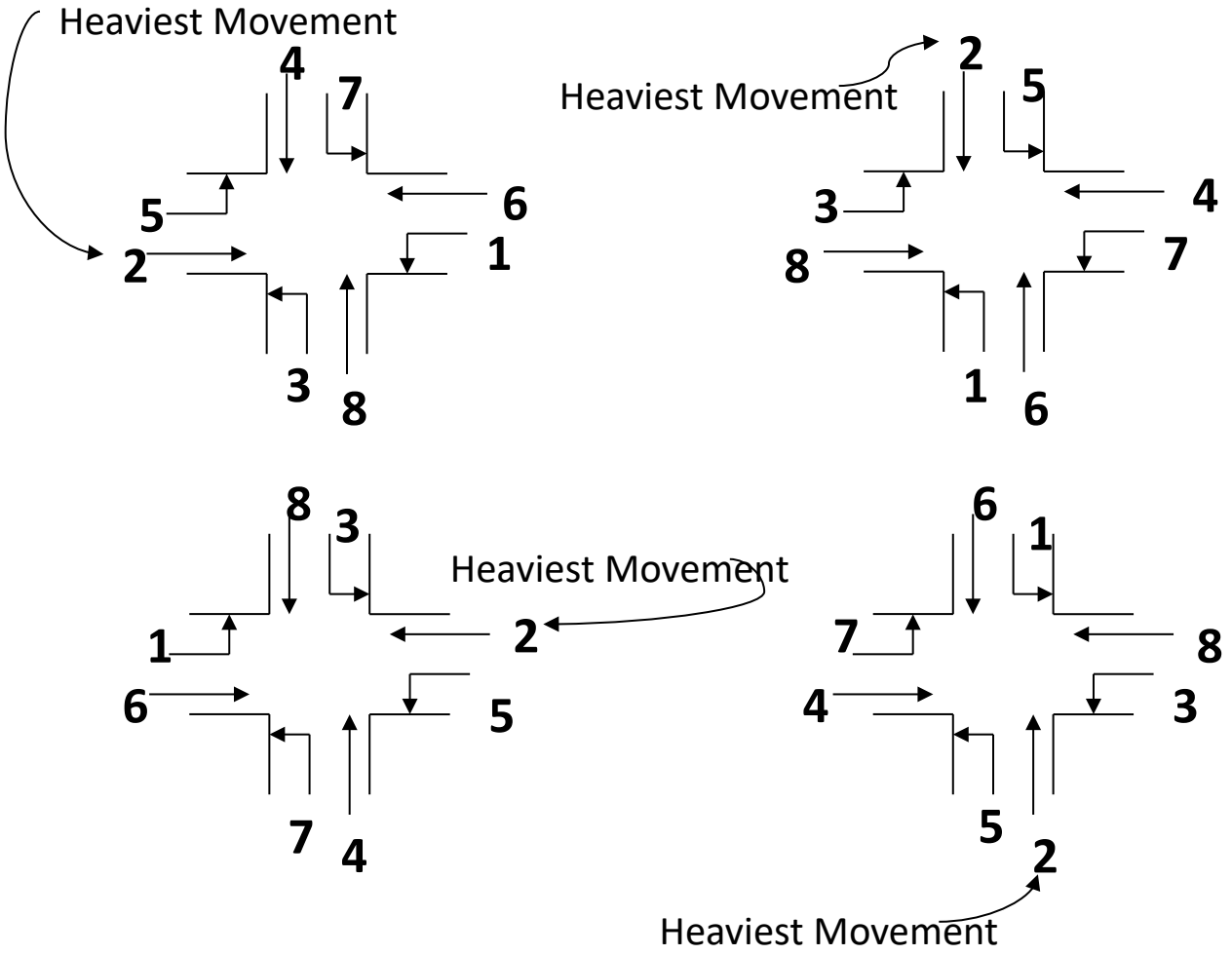


NEMA Phasing Convention

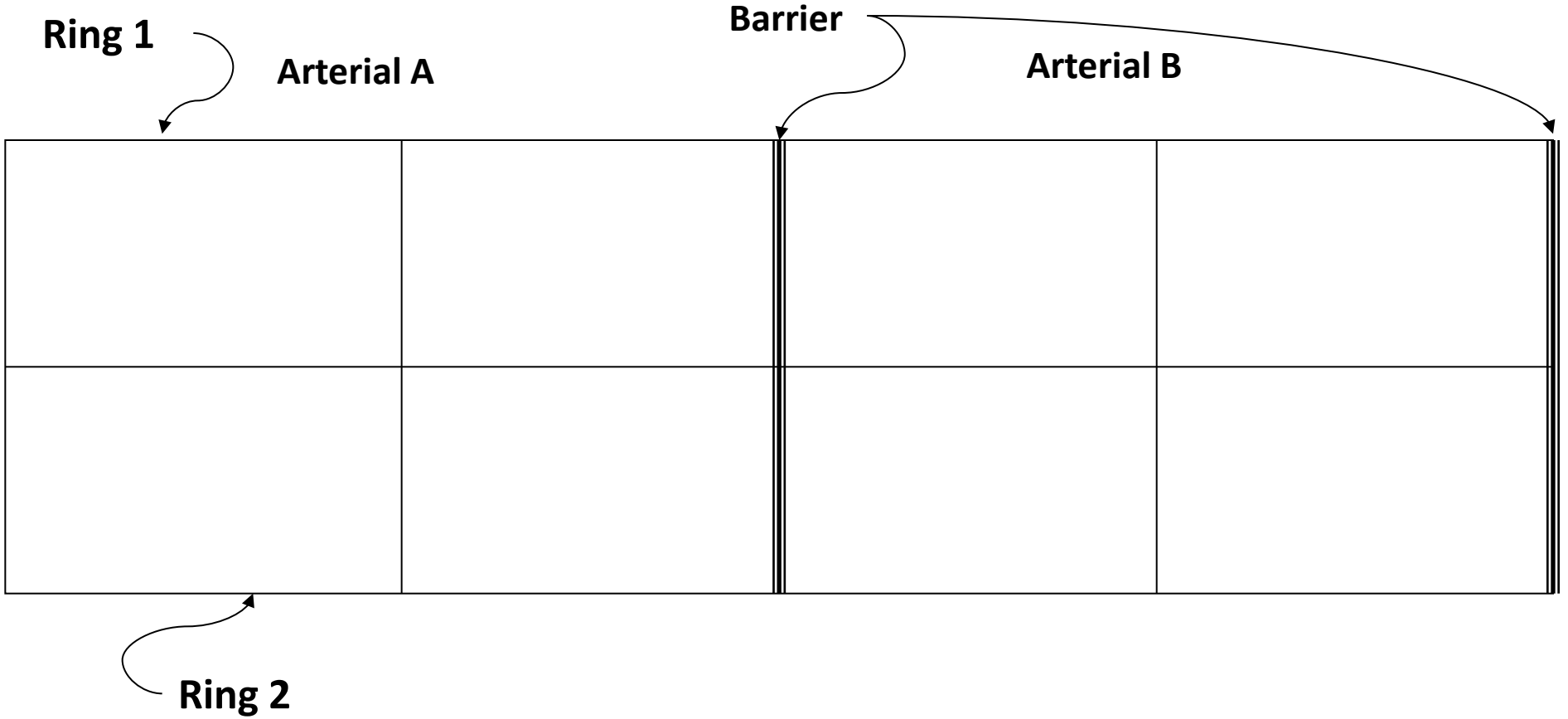
- Through Movements: **Even numbers** clockwise starting with heaviest movement
- Left Turn Movements: **Odd numbers one less than opposing through movement designation**
- (Bold is mandatory)



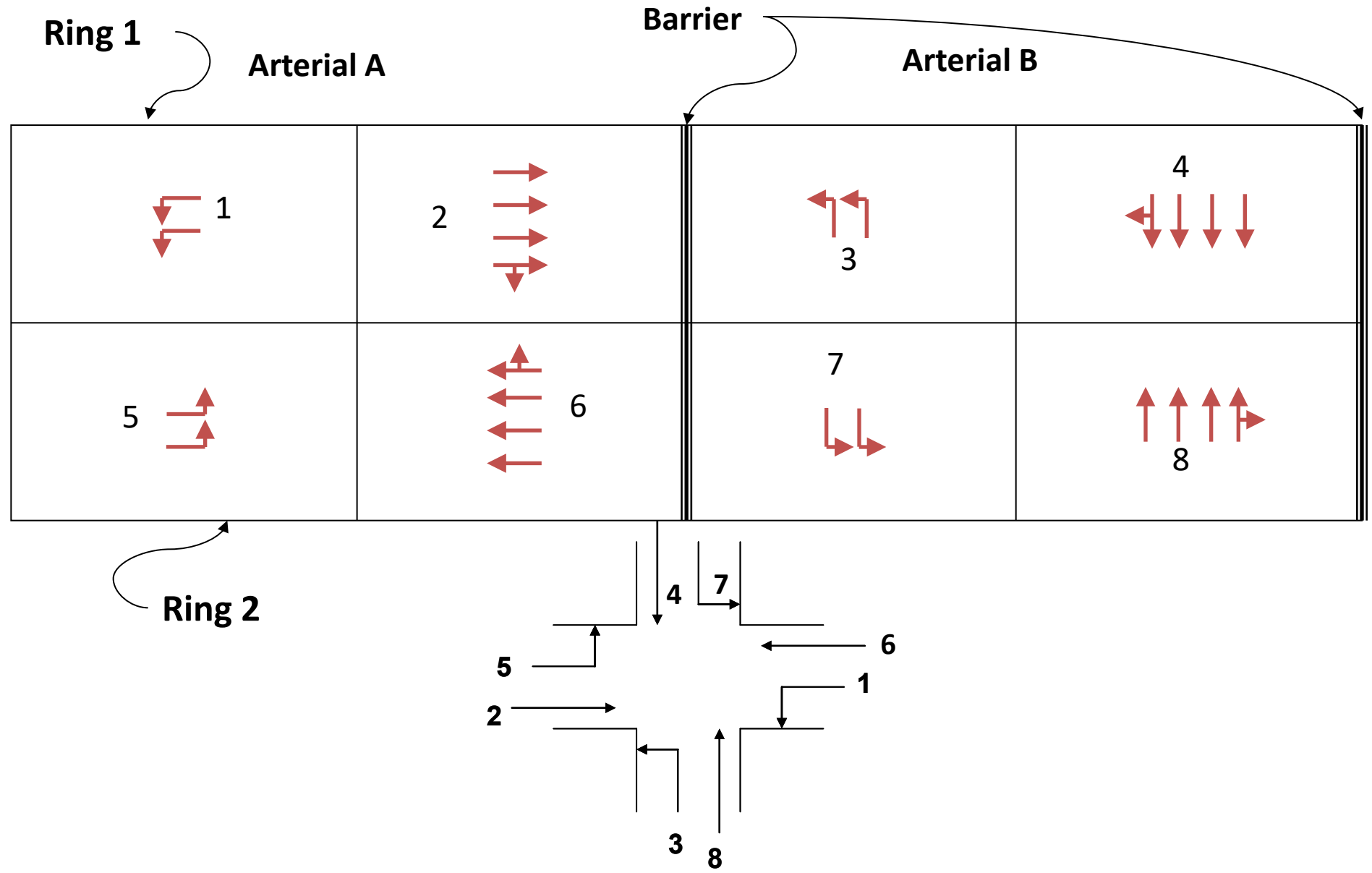
NEMA Phasing Convention



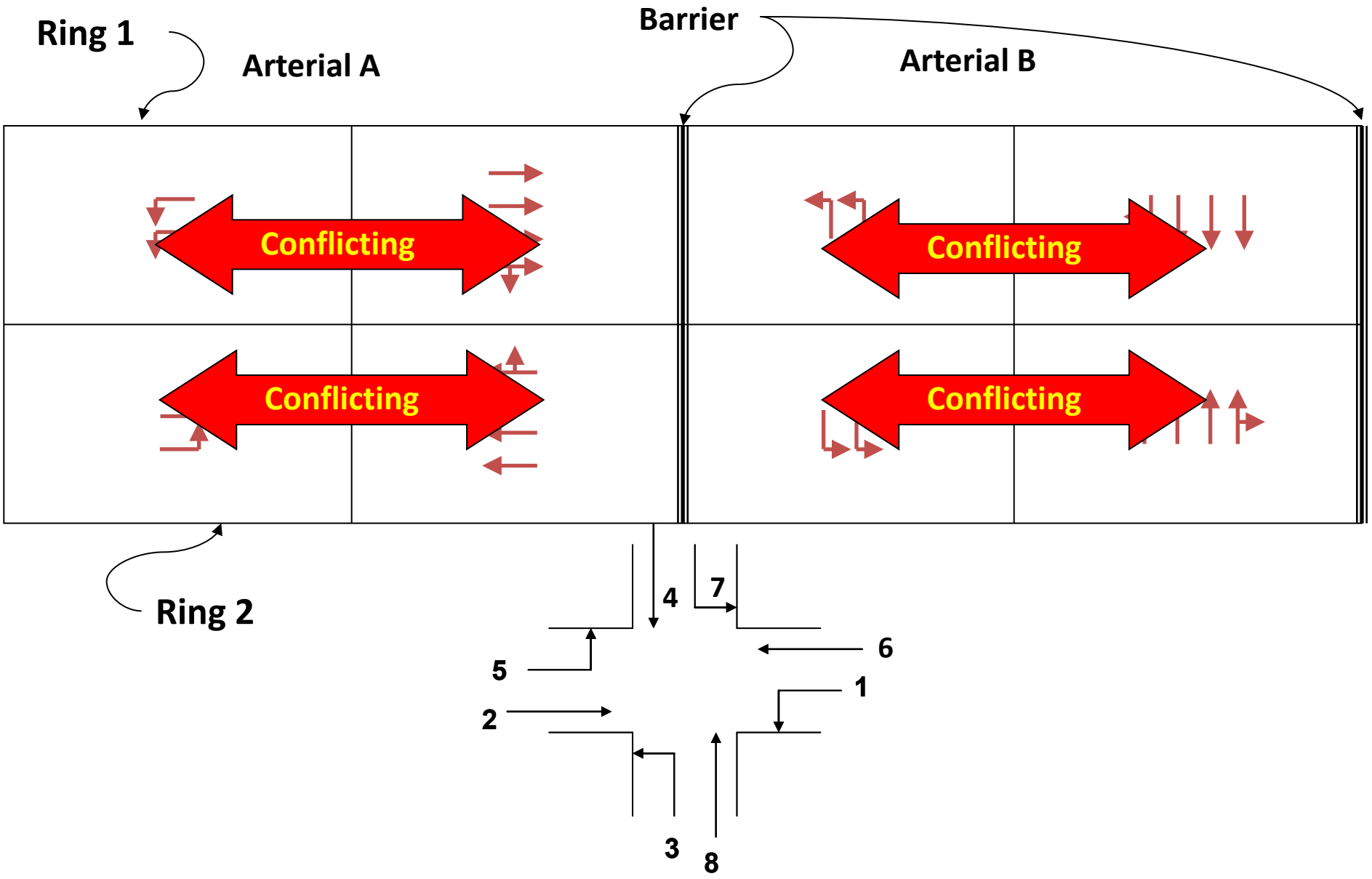
PHASING DIAGRAM RULES



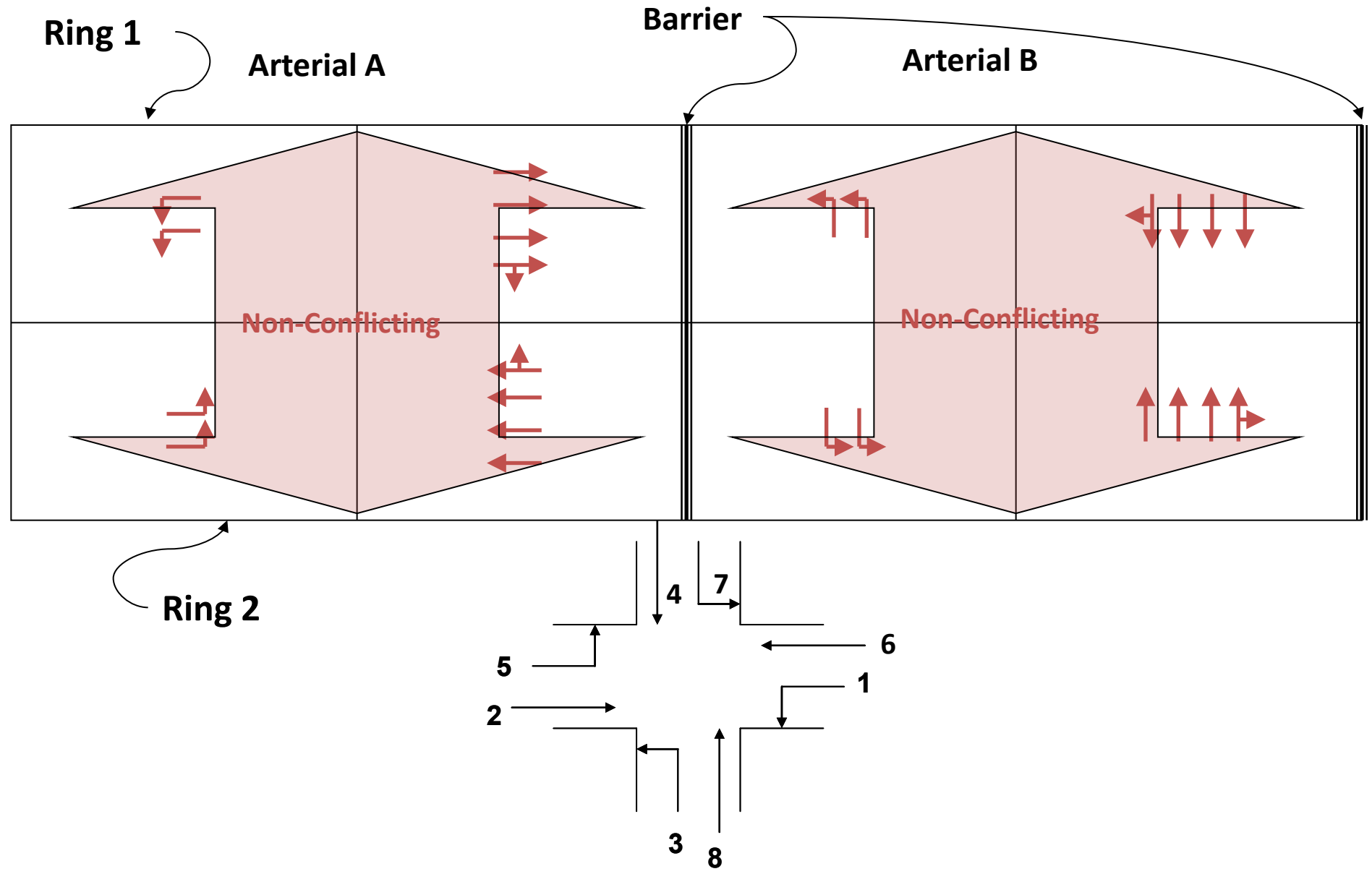
PHASING DIAGRAM RULES



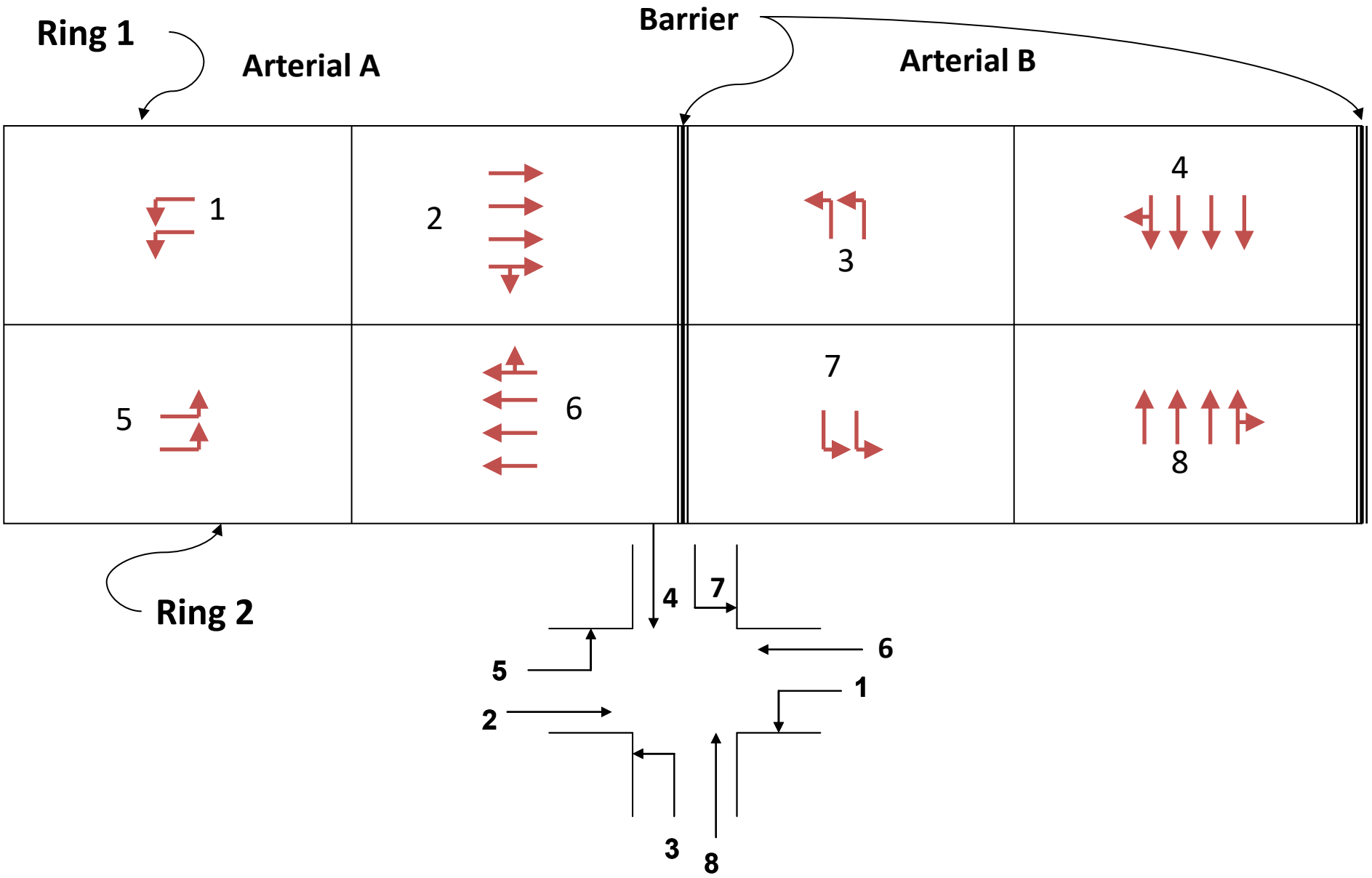
PHASING DIAGRAM RULES



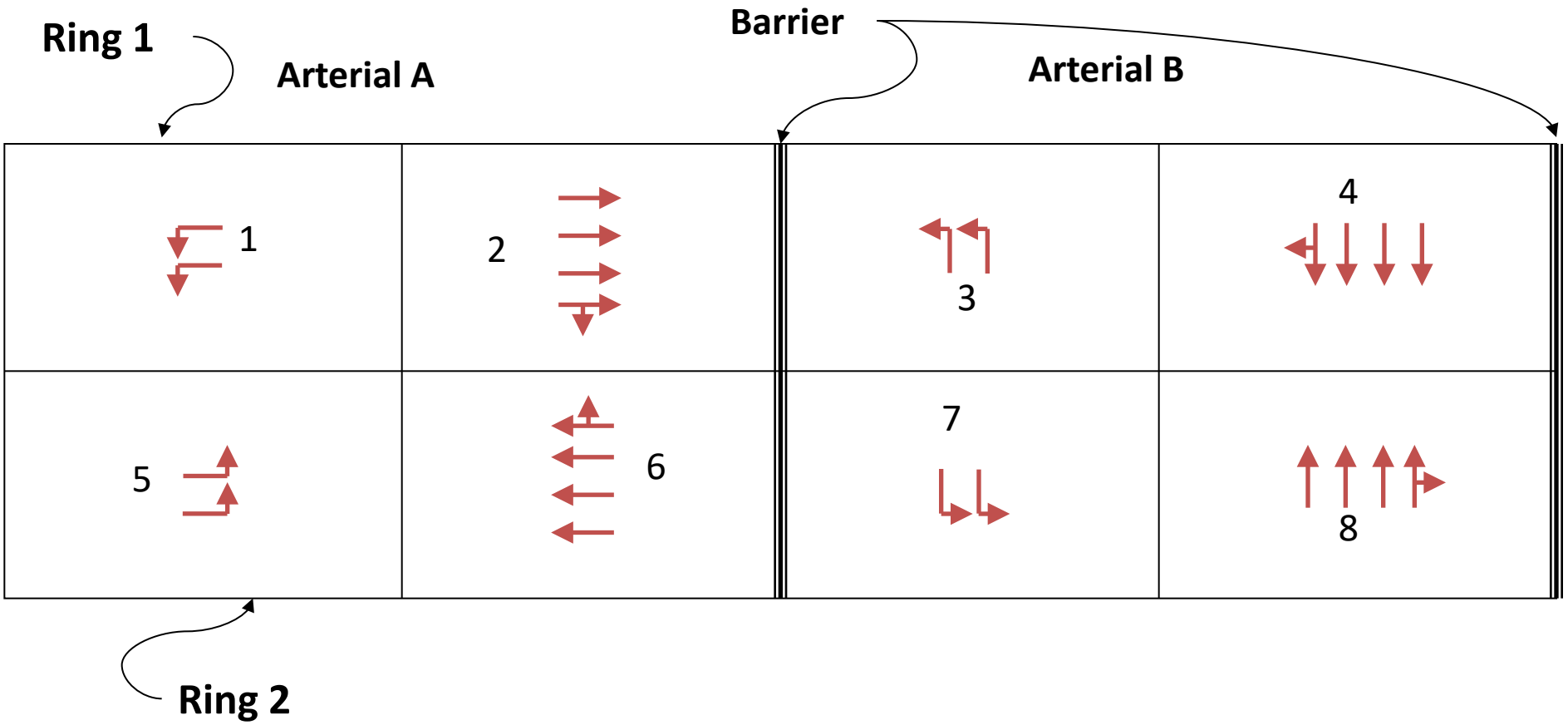
PHASING DIAGRAM RULES



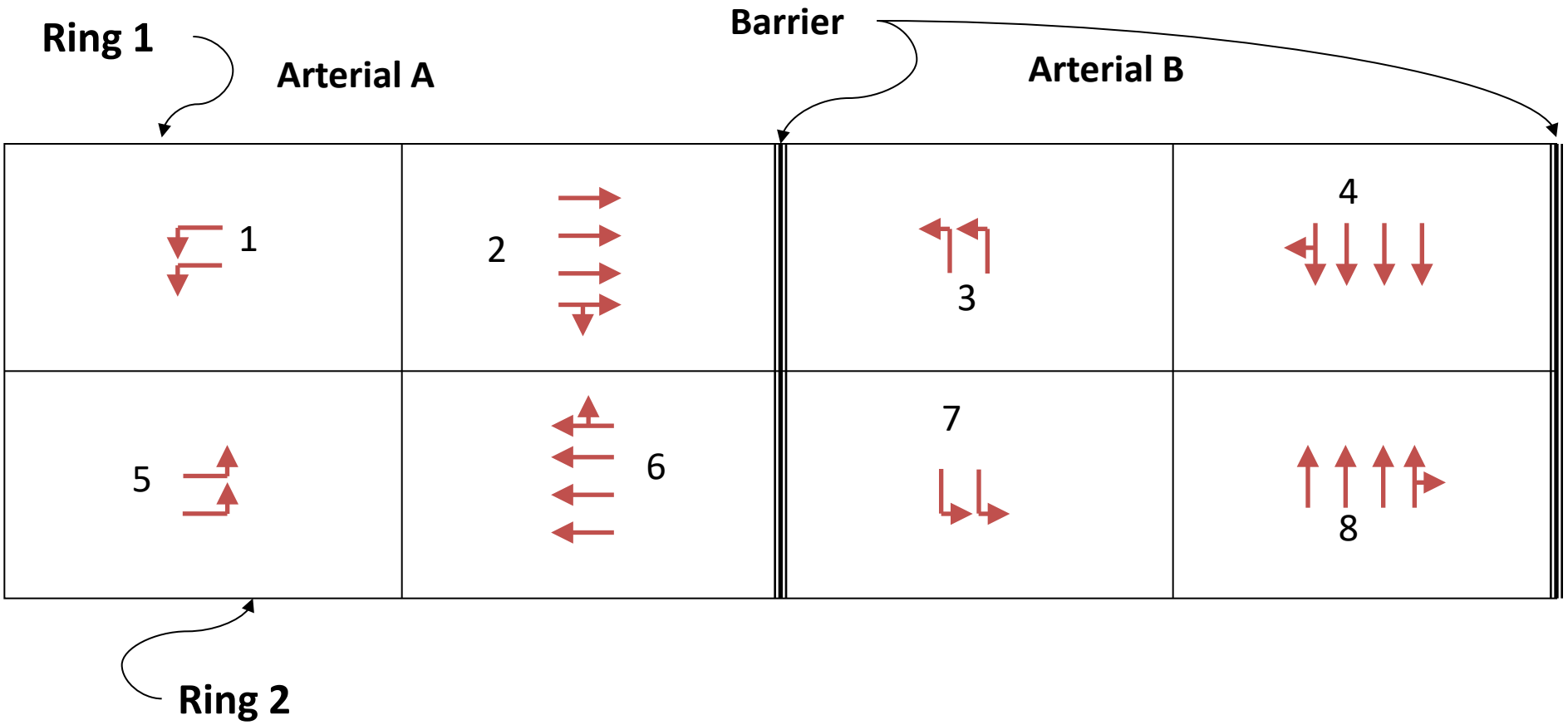
PHASING DIAGRAM RULES



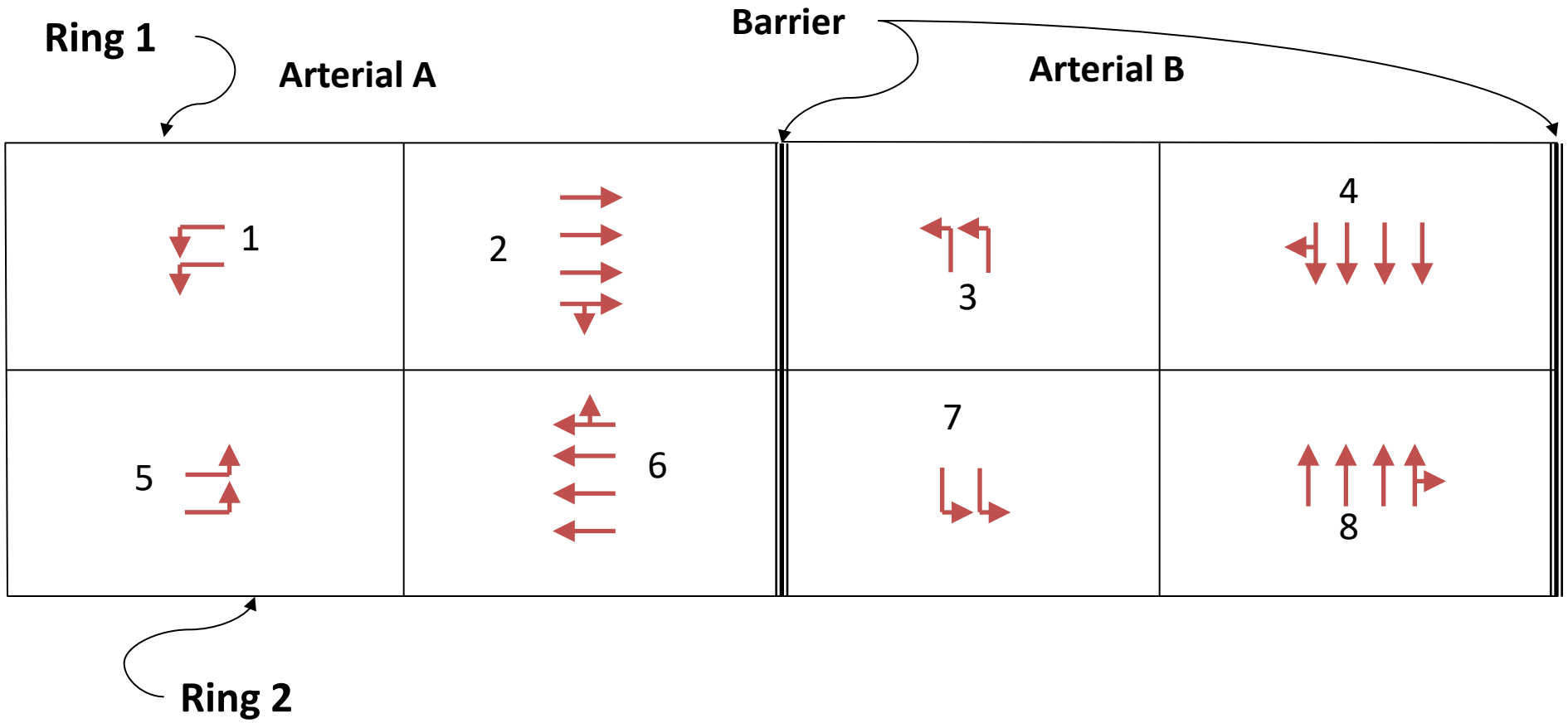
PHASING DIAGRAM RULES



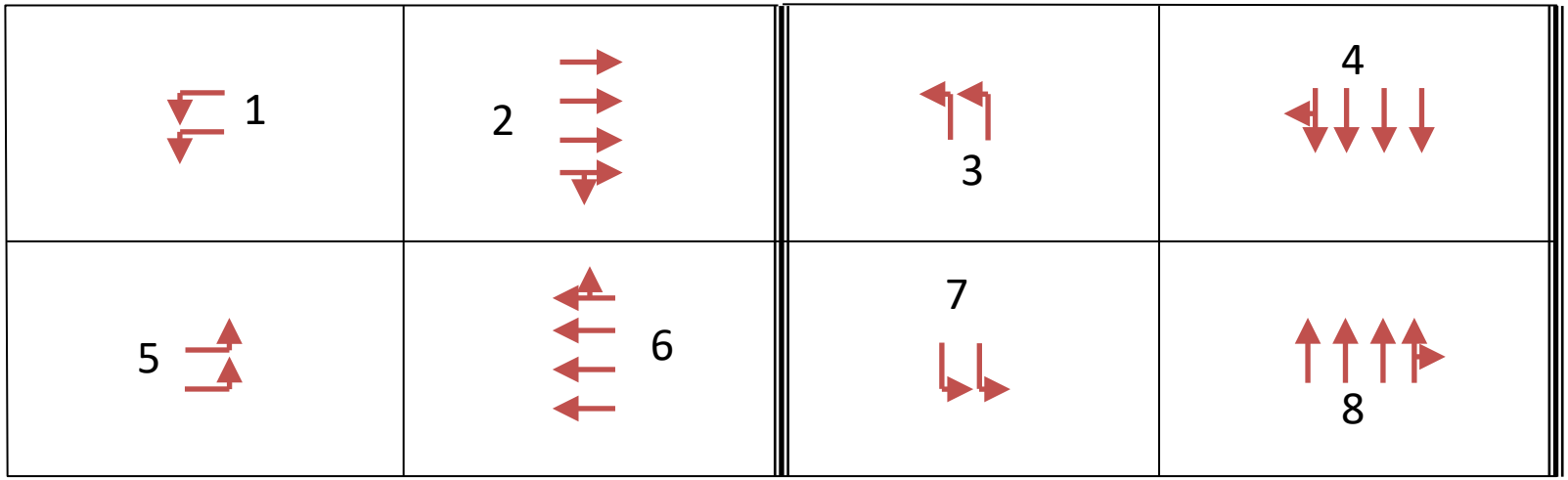
PHASING DIAGRAM RULES



PHASING DIAGRAM RULES

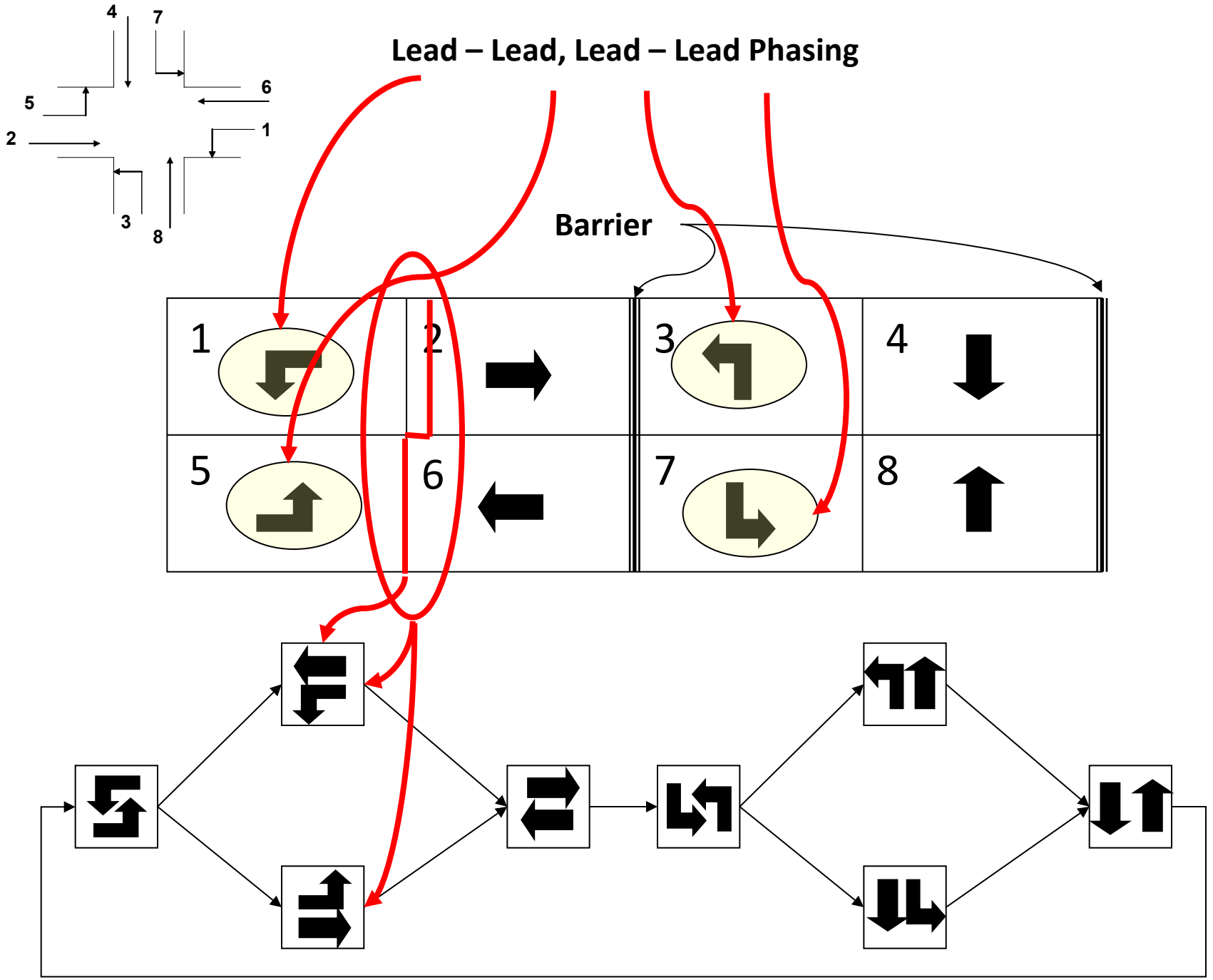


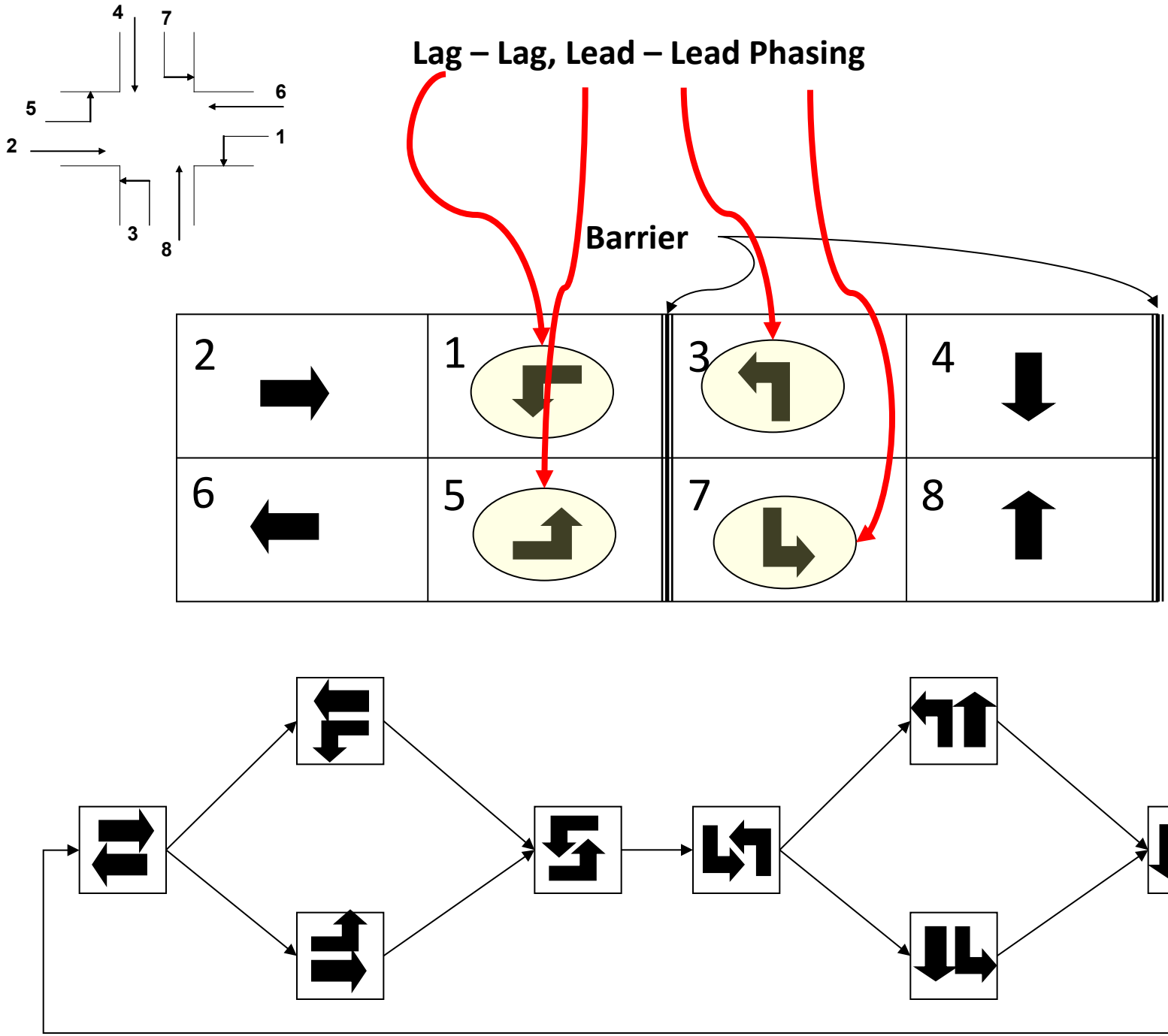
Traffic Signal Constraints

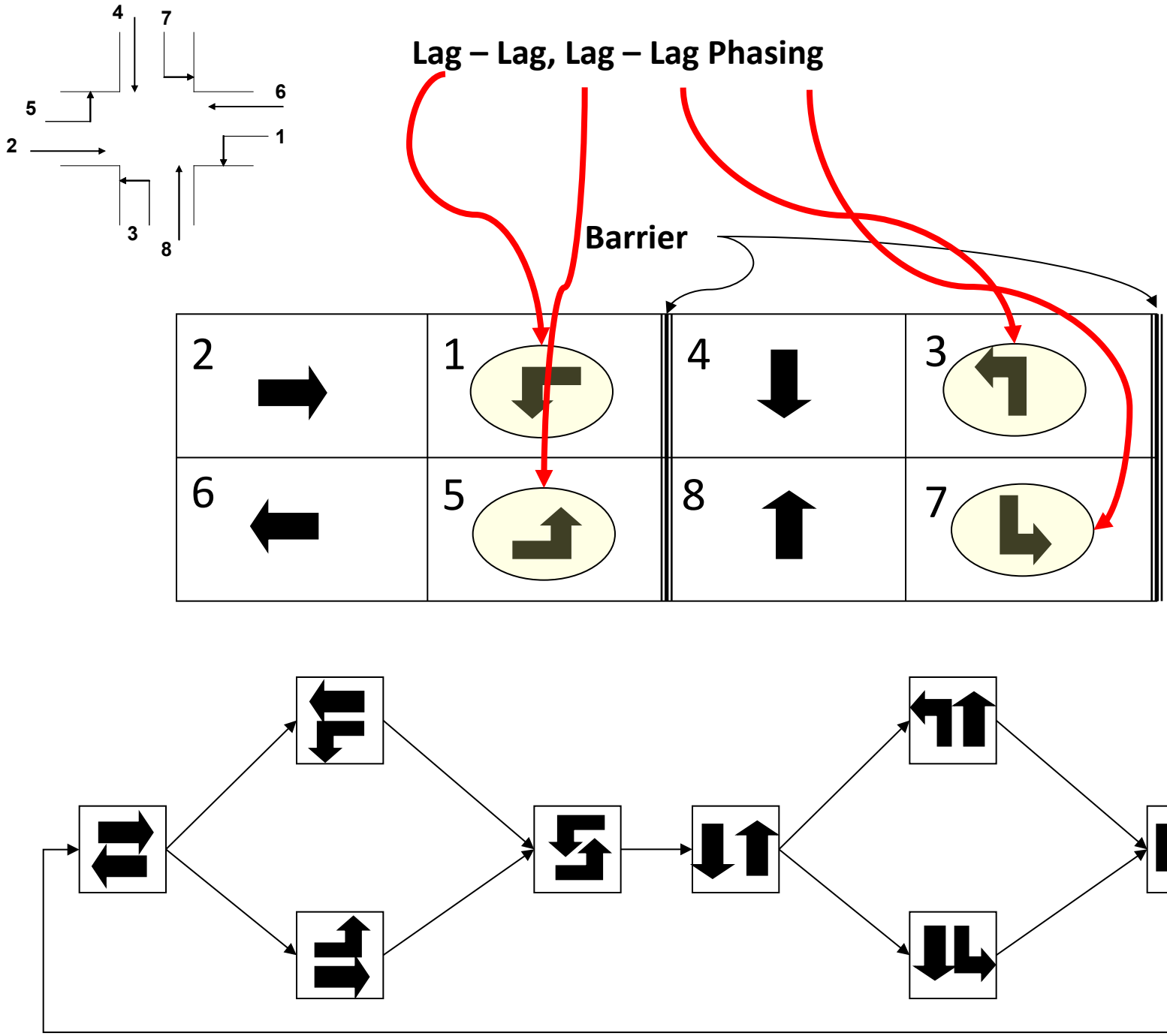


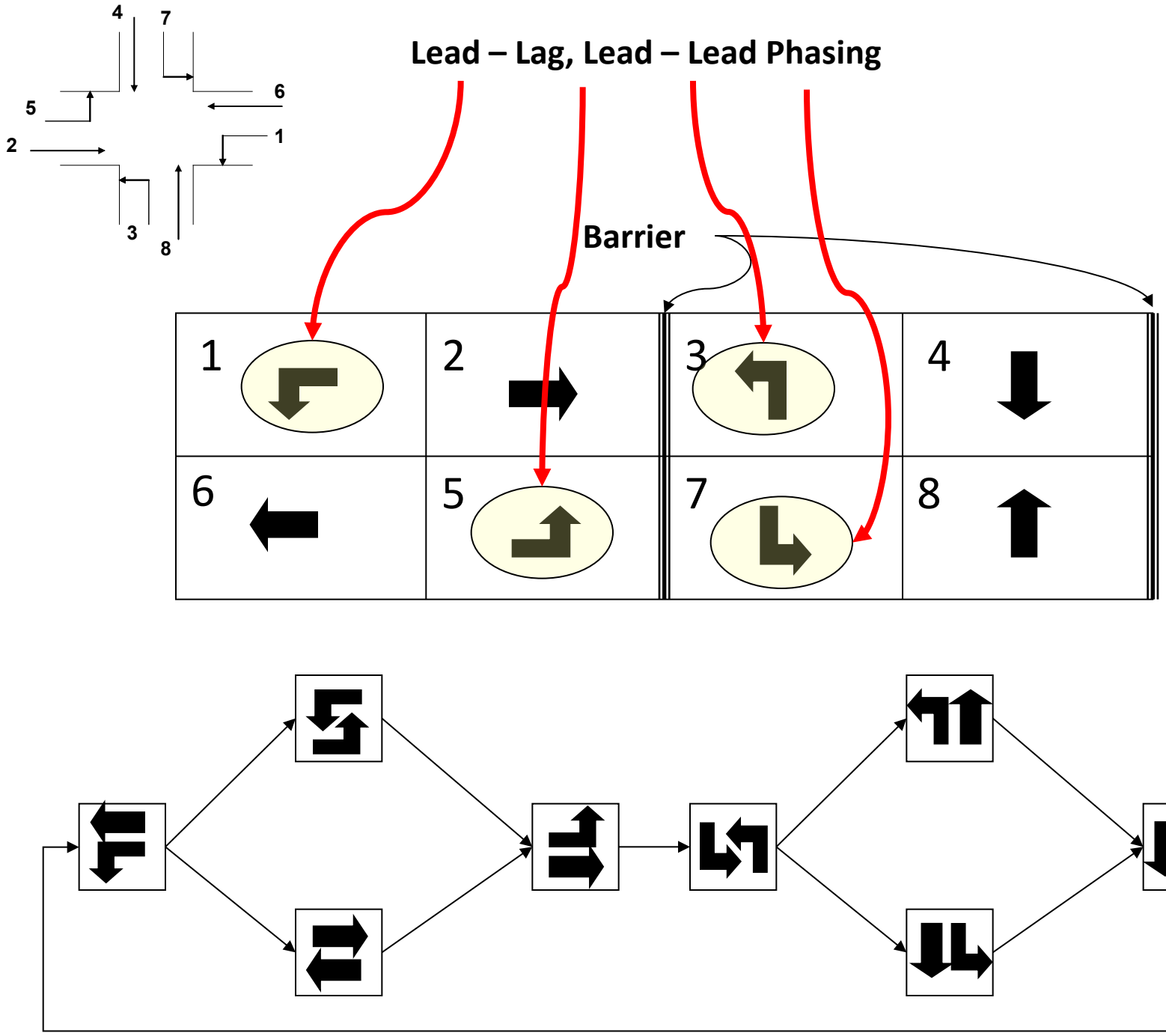
$$\begin{cases} g_1 + g_2 = g_5 + g_6 \\ g_3 + g_4 = g_7 + g_8 \\ g_1 + g_2 + g_3 + g_4 = C \end{cases} \qquad g_1 = g_5?$$

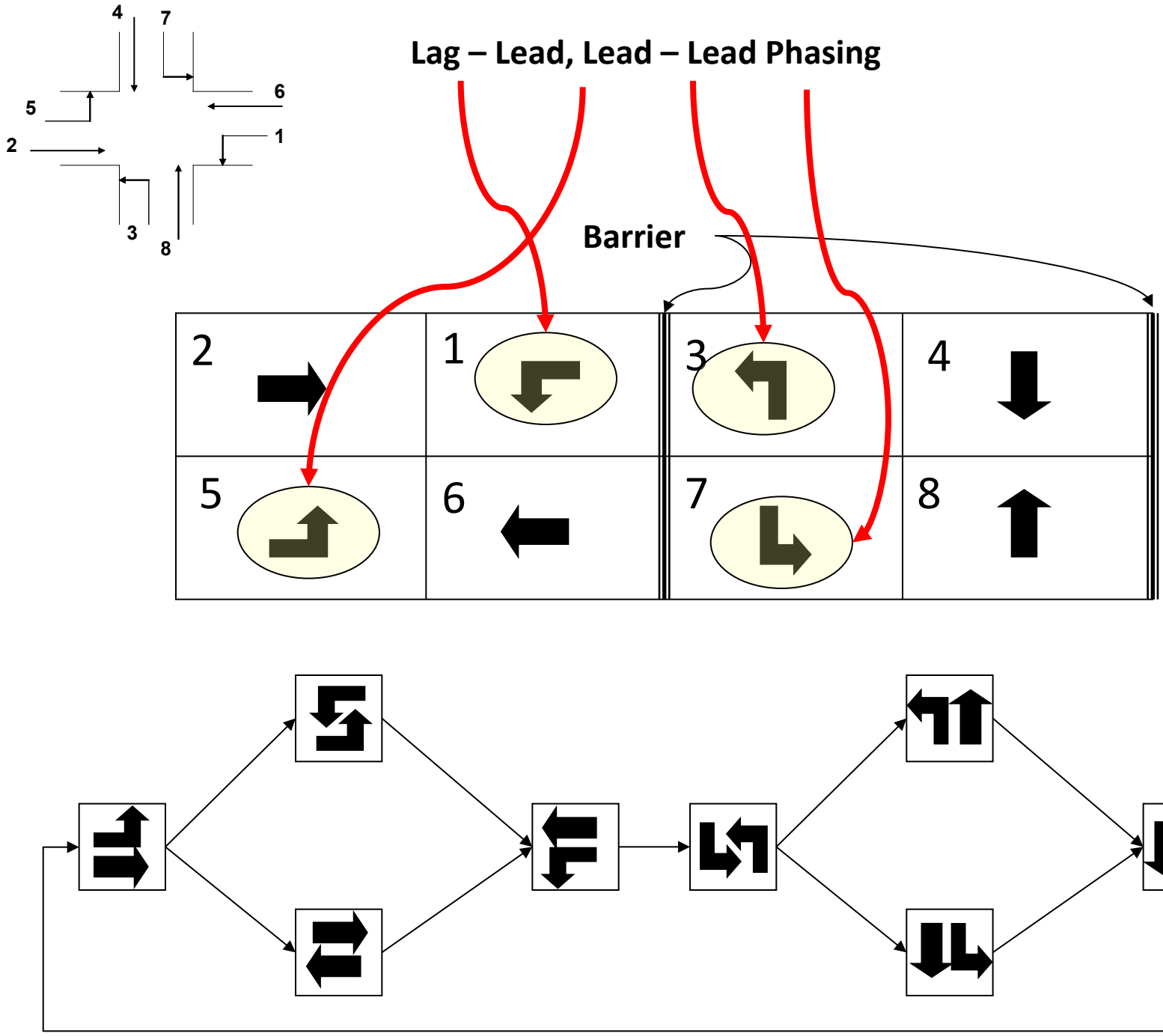
Lead – Lead, Lead – Lead Phasing



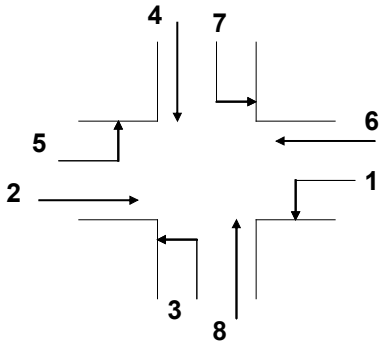

Lag – Lag, Lead – Lead Phasing
Barrier
4
7
6
5
2
1
3
8
2
1
3
4
6
5
7
8

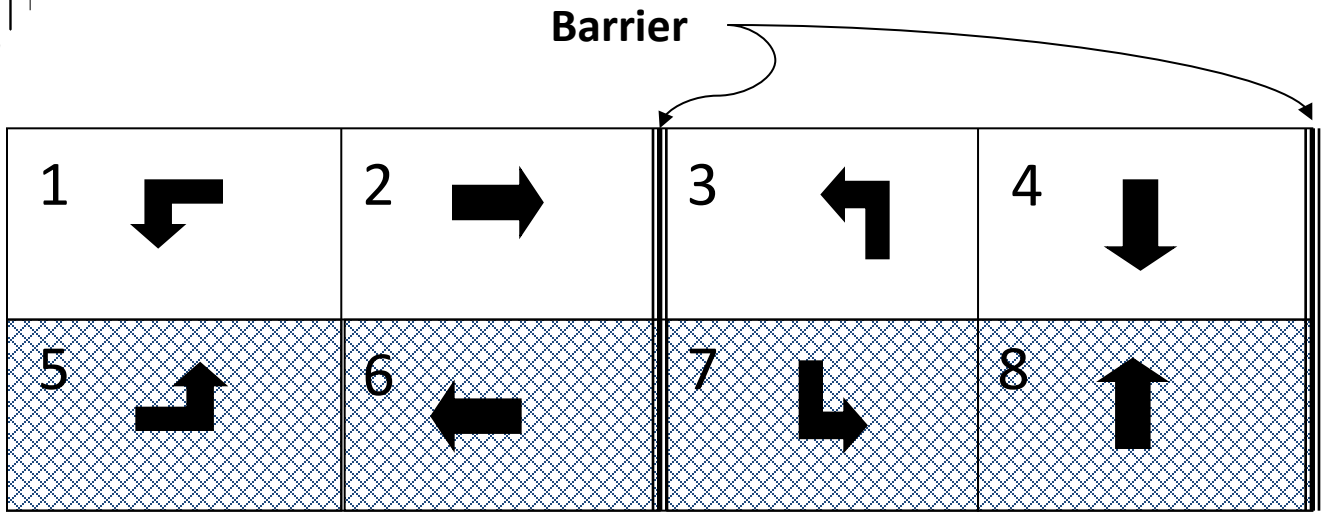

4
7
6
5
2
1
3
8
Lag – Lag, Lag – Lag Phasing
Barrier
2
1
4
3
6
5
8
7

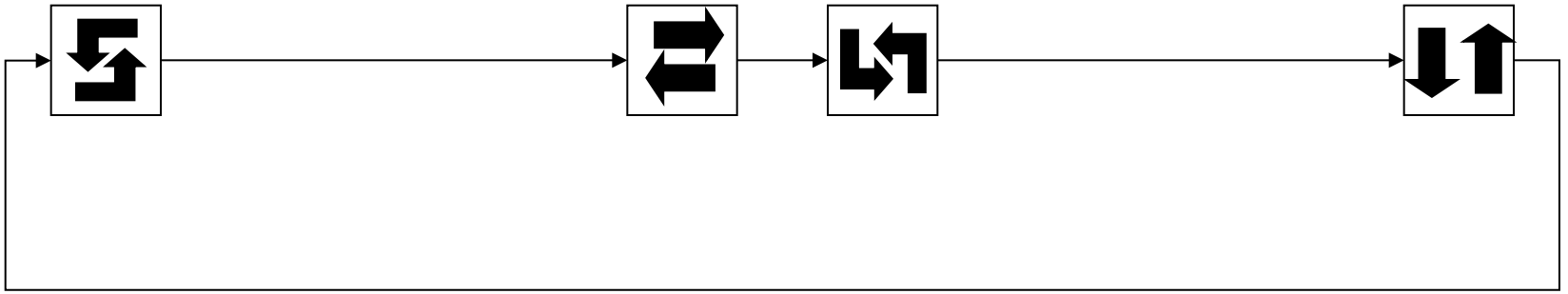

Lead – Lag, Lead – Lead Phasing
4
7
6
5
2
1
3
8
Barrier
1
2
3
4
6
5
7
8


Lag – Lead, Lead – Lead Phasing
Barrier
4
7
6
5
2
1
3
8
2
1
3
4
5
6
7
8

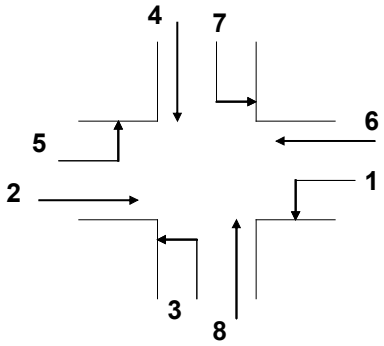
4 Phase Single Ring Operation

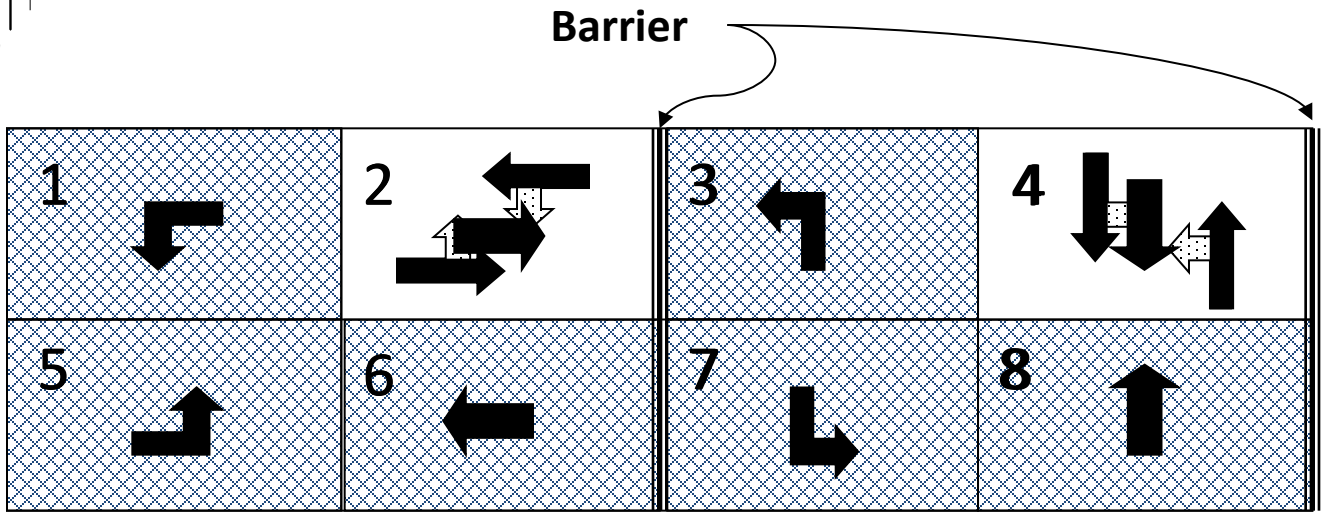


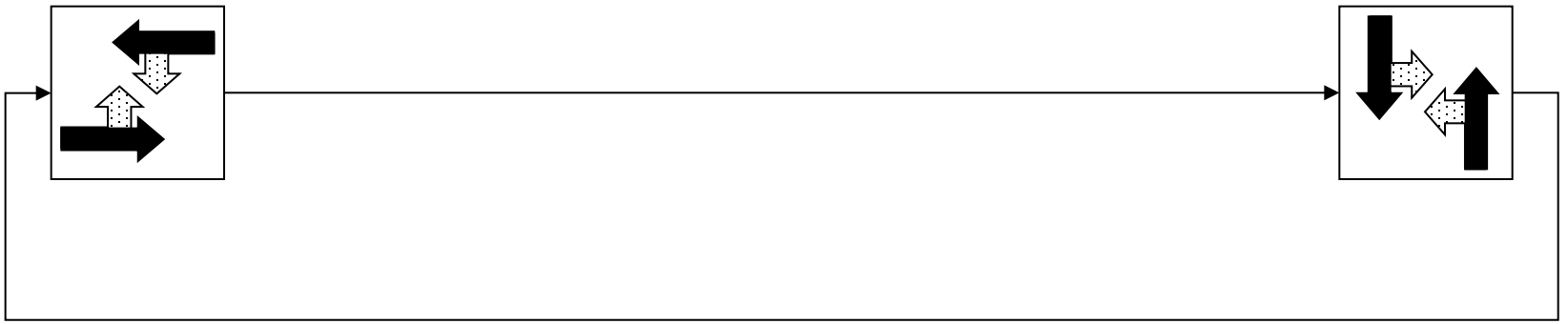




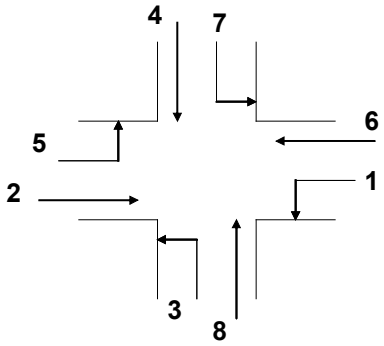
2 Phase Single Ring Operation

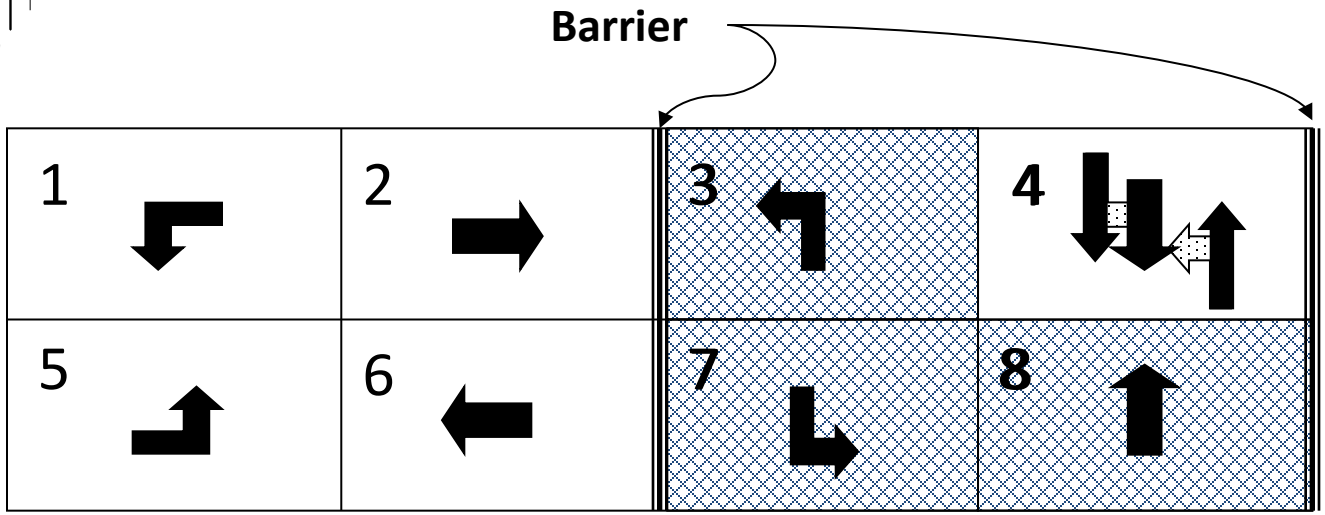


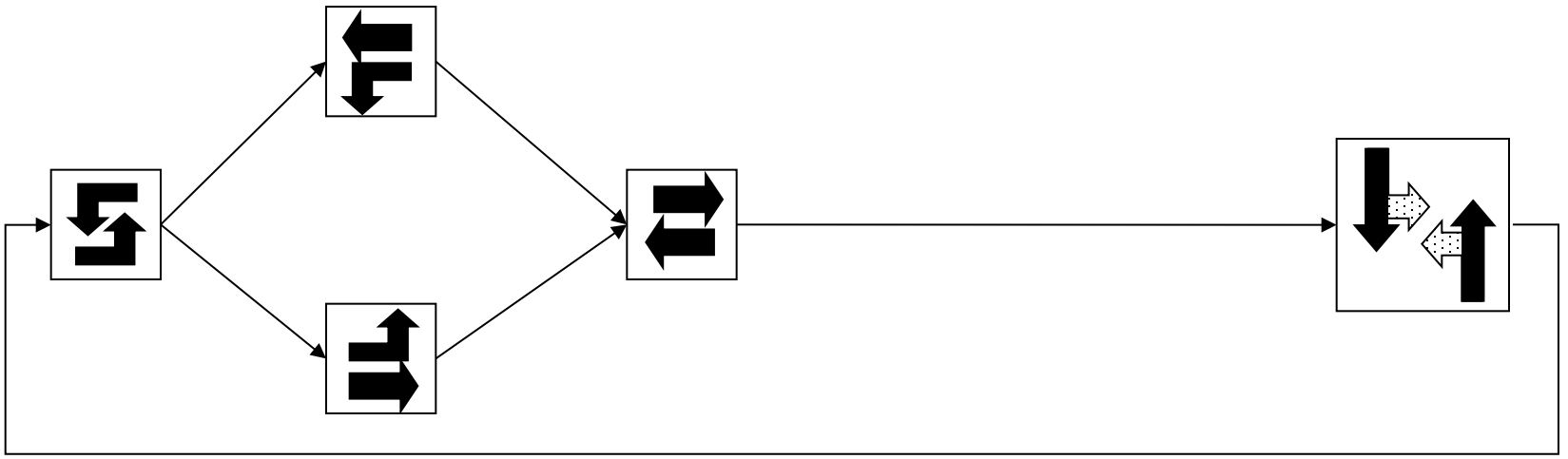




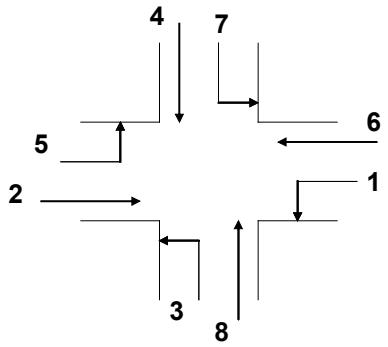
5 Phase Dual Ring Operation

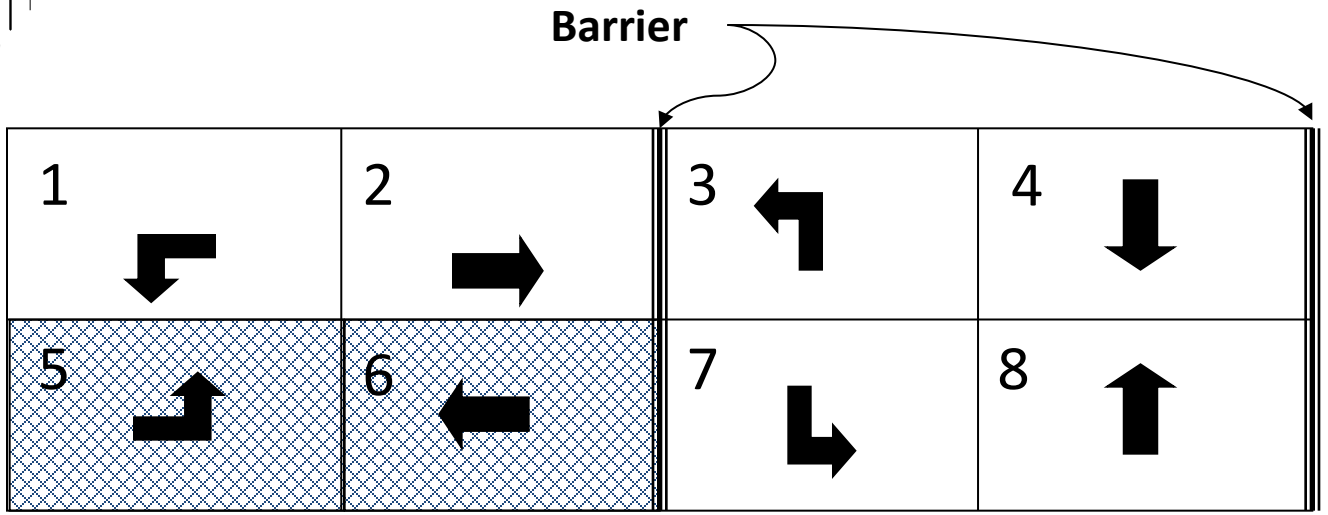


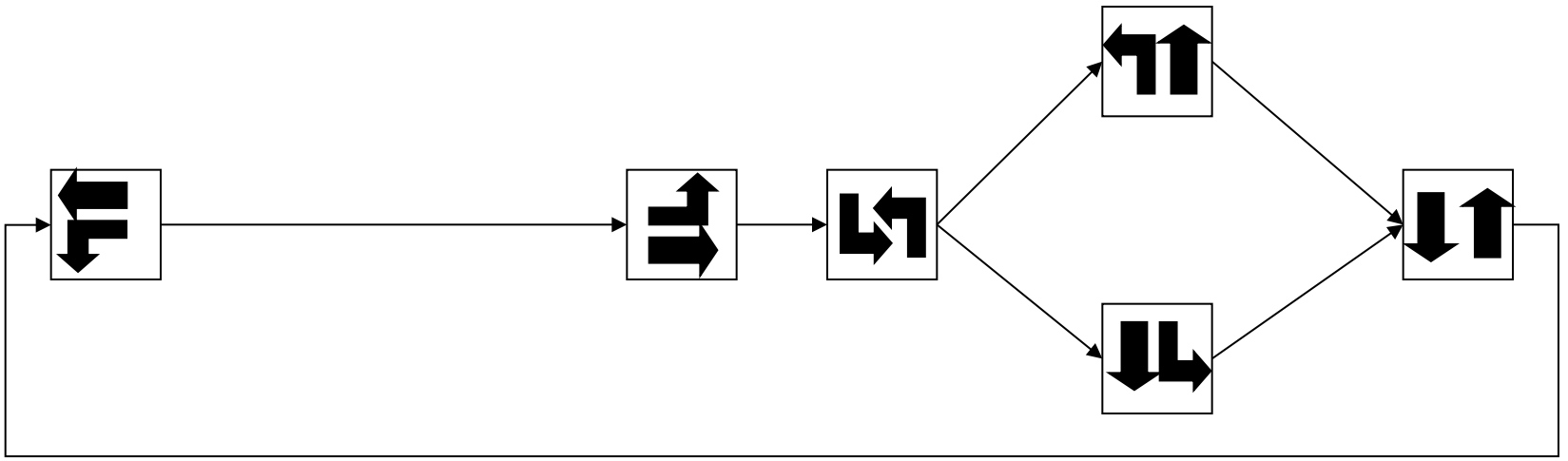




Split Phasing on Arterial A





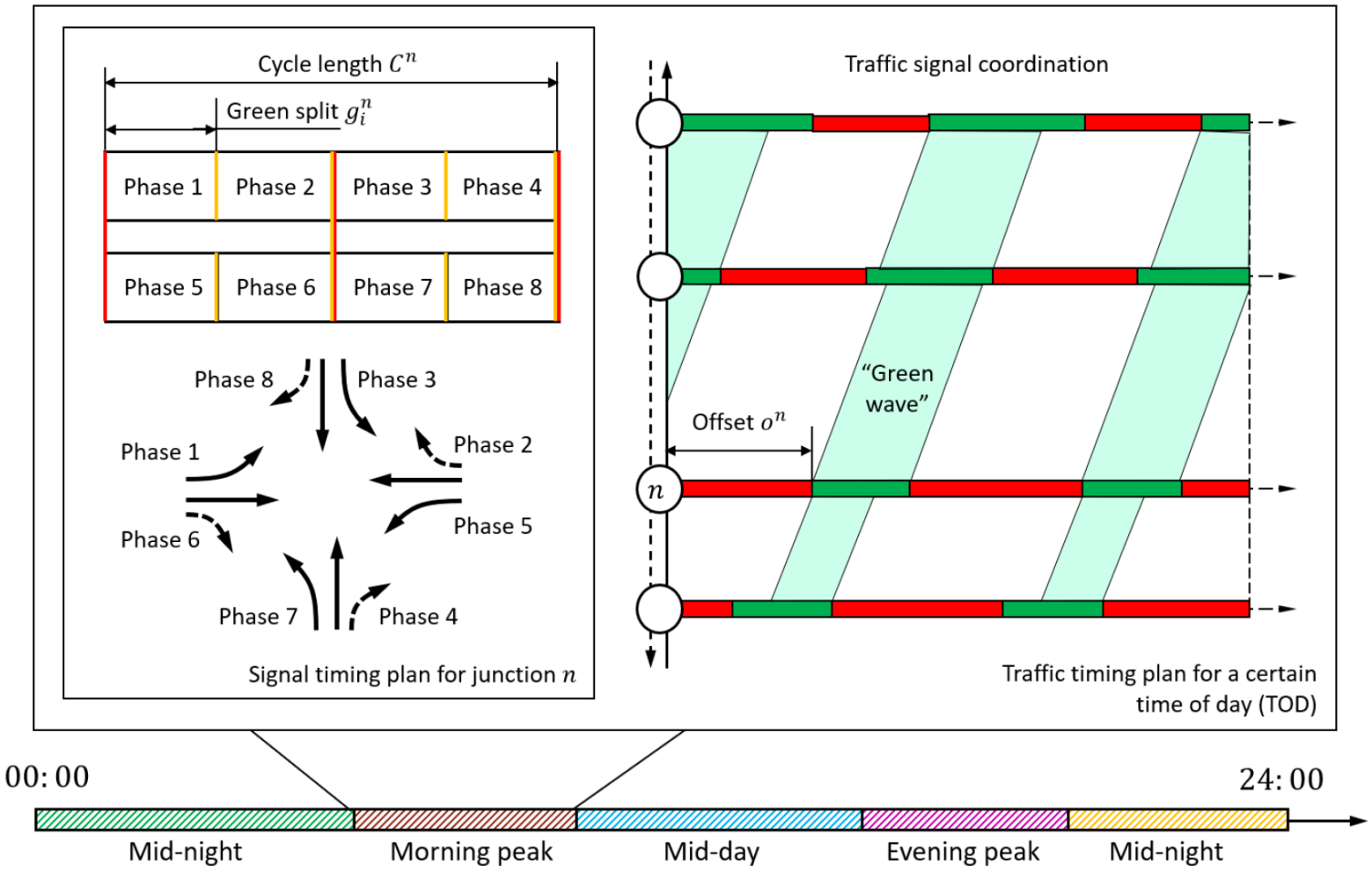


Fixed-Time Signal Timing Parameters

- Cycle length
- Phase sequence
- Green spilt

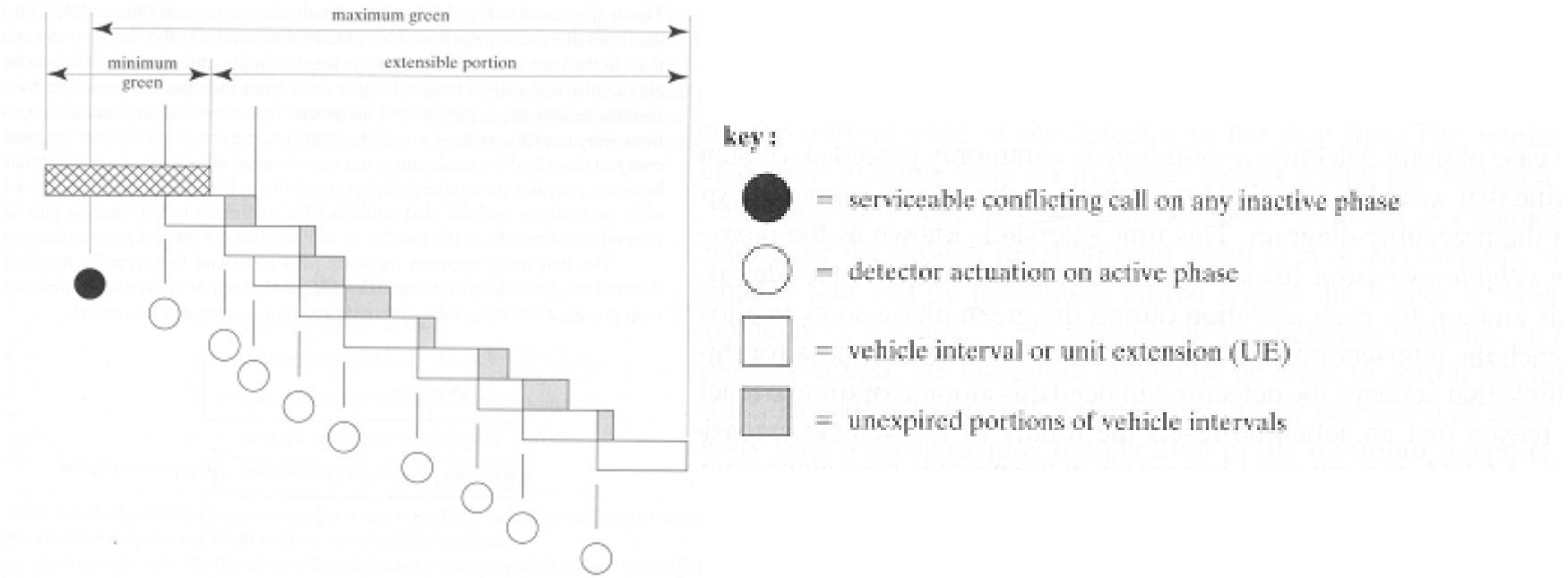
- Time of day plans
- More in the next lecture

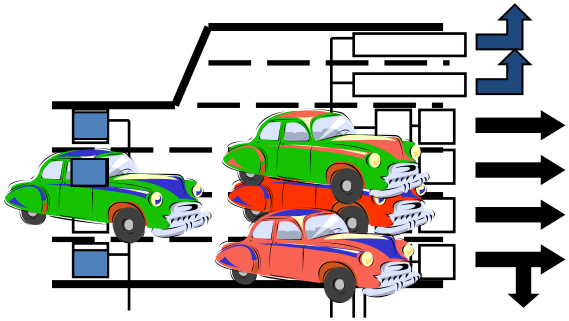
Main Parameters

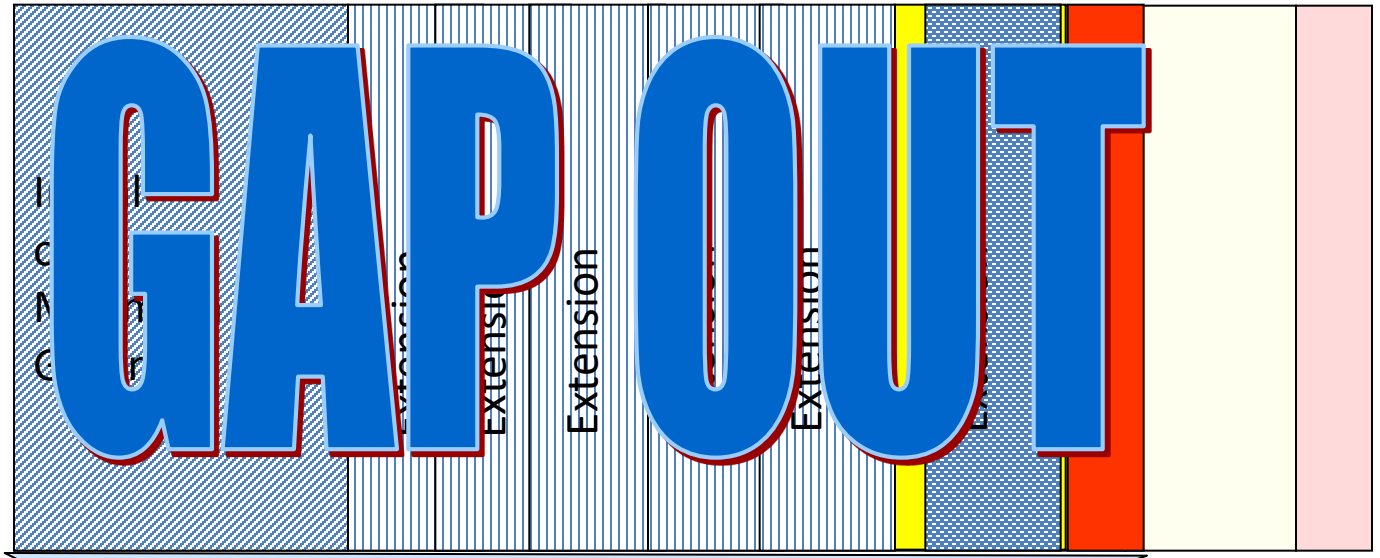


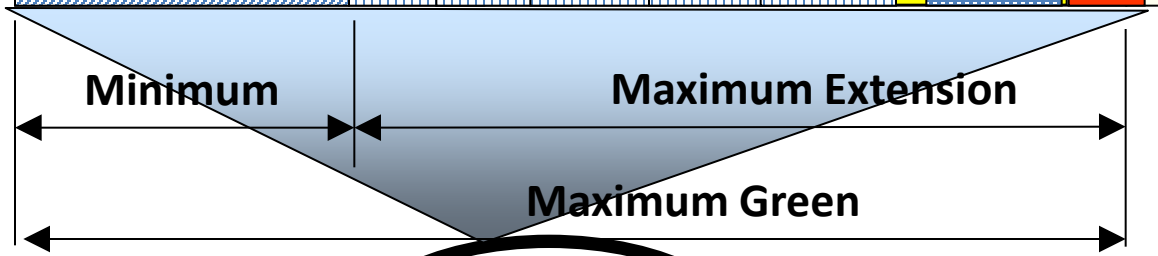
Actuated Control Logic

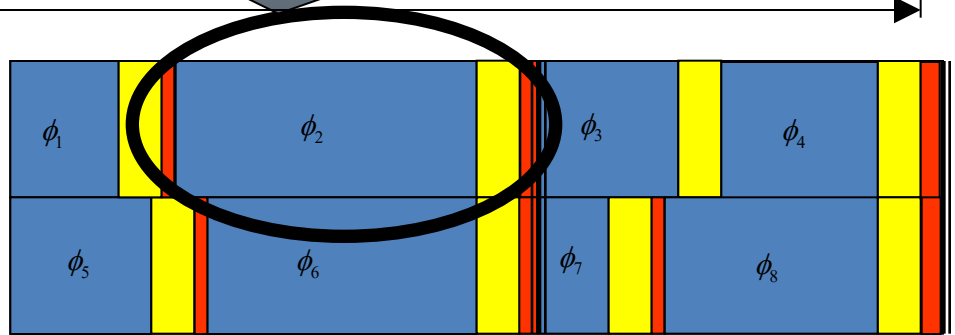
- Minimal green
- Maximal green (max out)
- Unit extension (gap out)

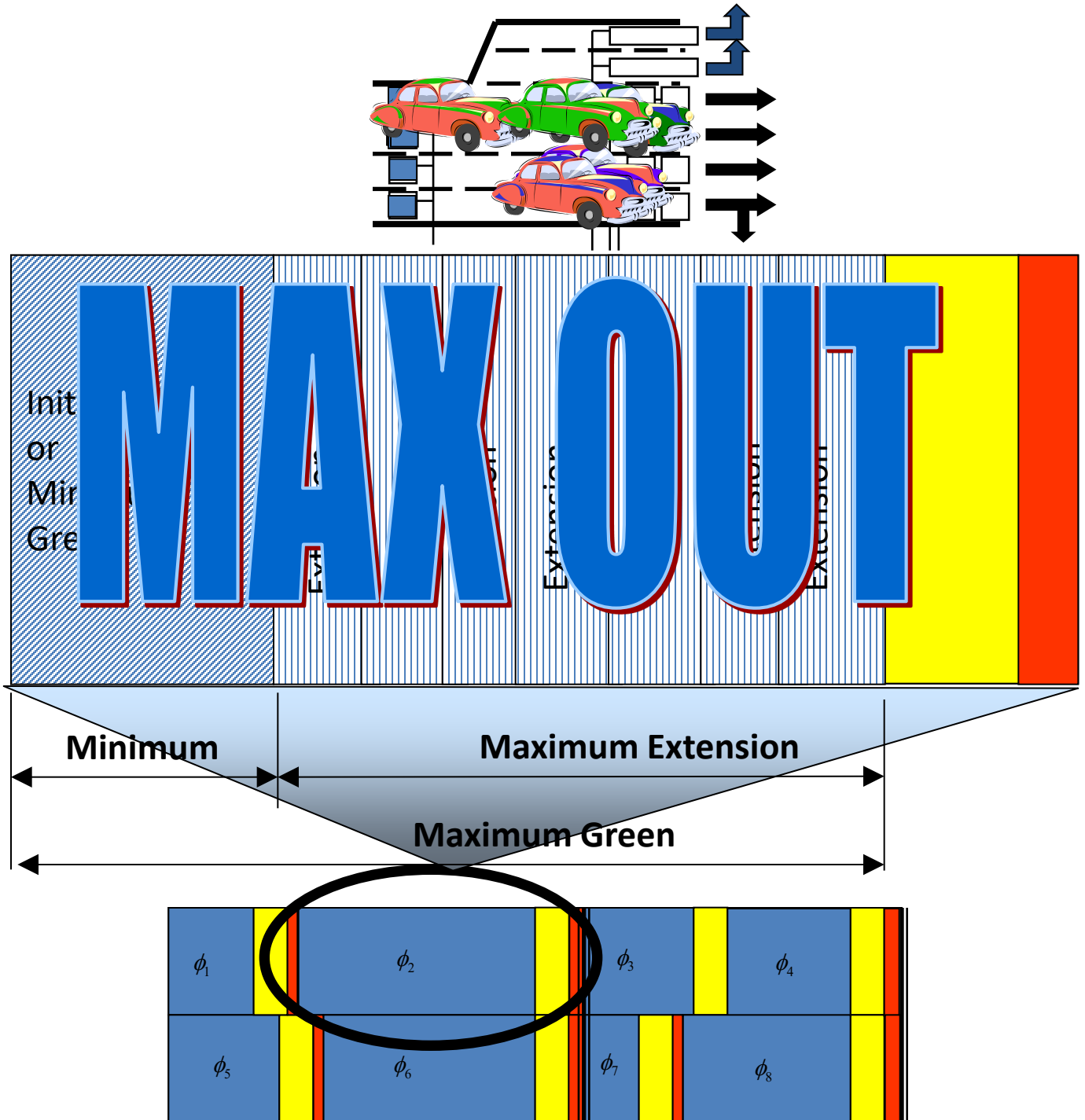


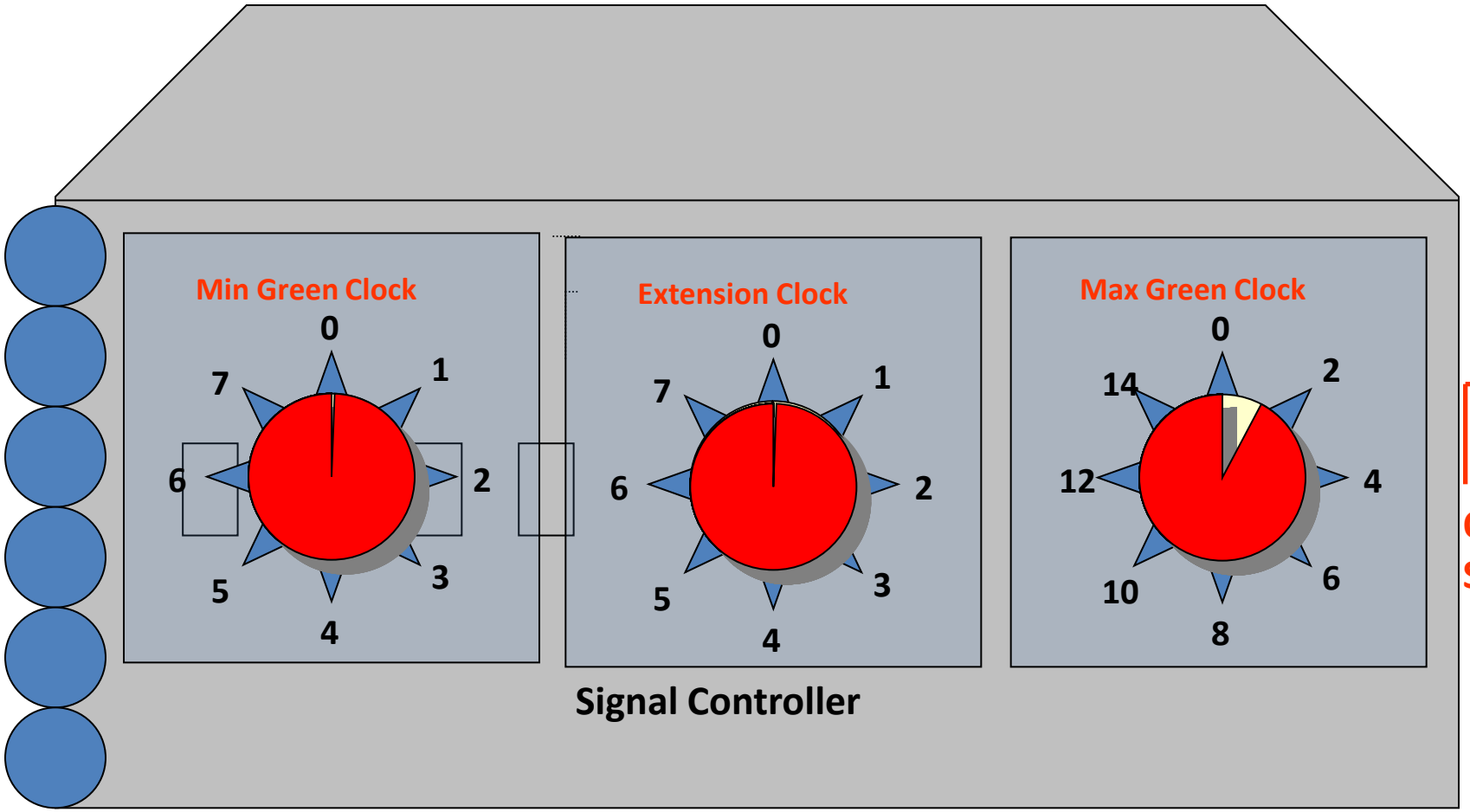



GAP OUT
Extension
Extension
Extension

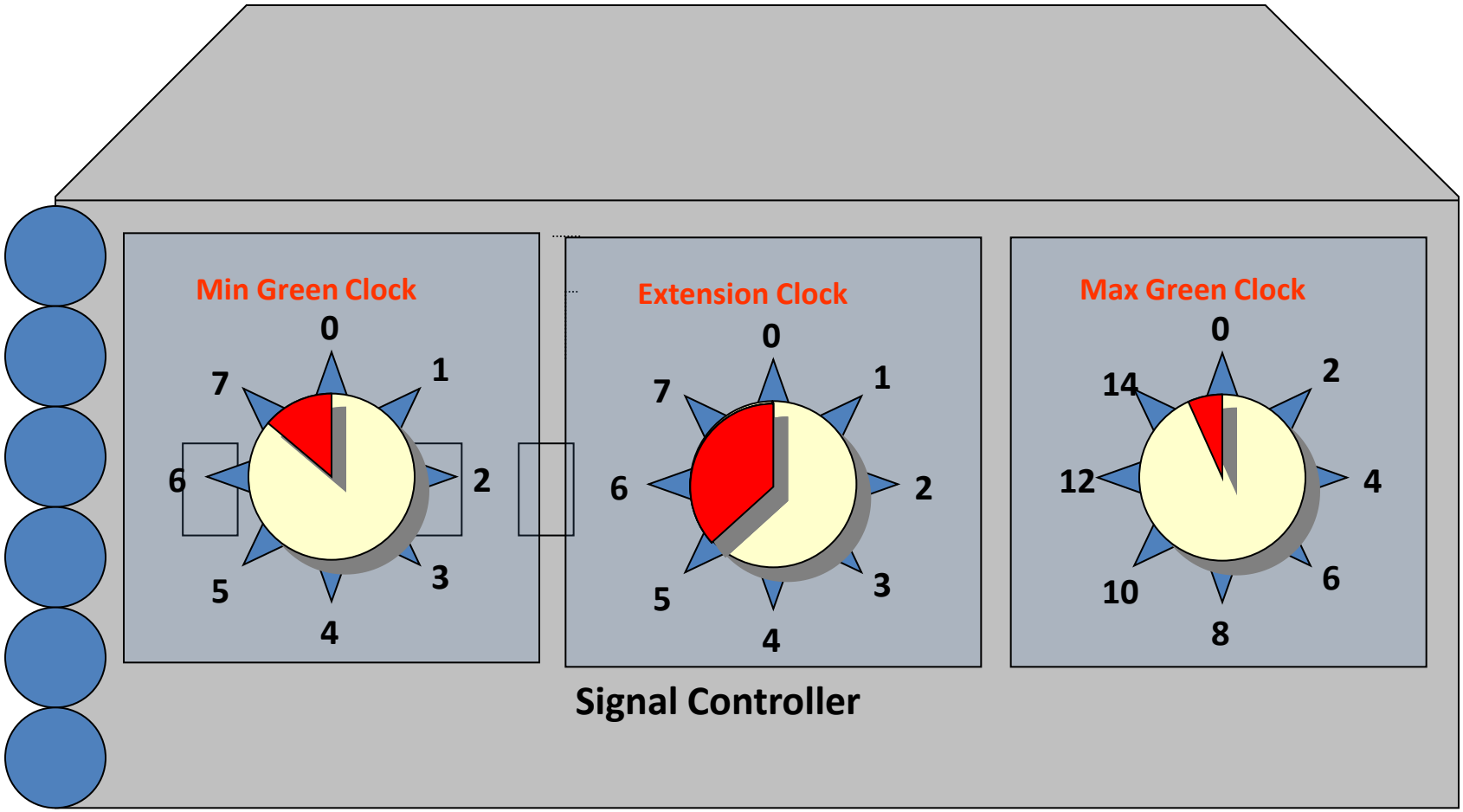

Minimum
Maximum Extension
Maximum Green


ϕ_1
ϕ_2
ϕ_3
ϕ_4
ϕ_5
ϕ_6
ϕ_7
ϕ_8

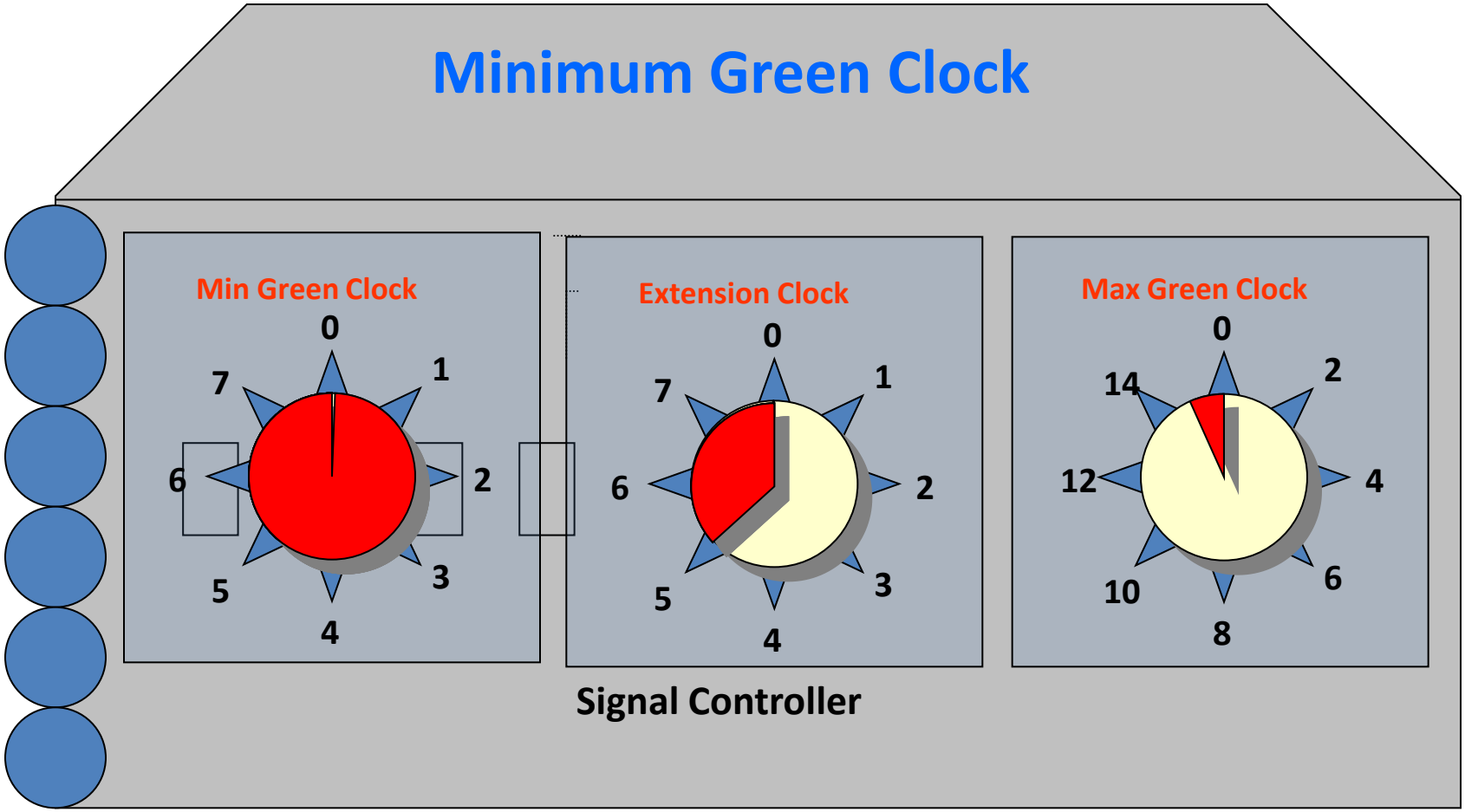

MAX OUT
Minimum
Maximum Extension
Maximum Green
ϕ_1
ϕ_2
ϕ_3
ϕ_4
ϕ_5
ϕ_6
ϕ_7
ϕ_8



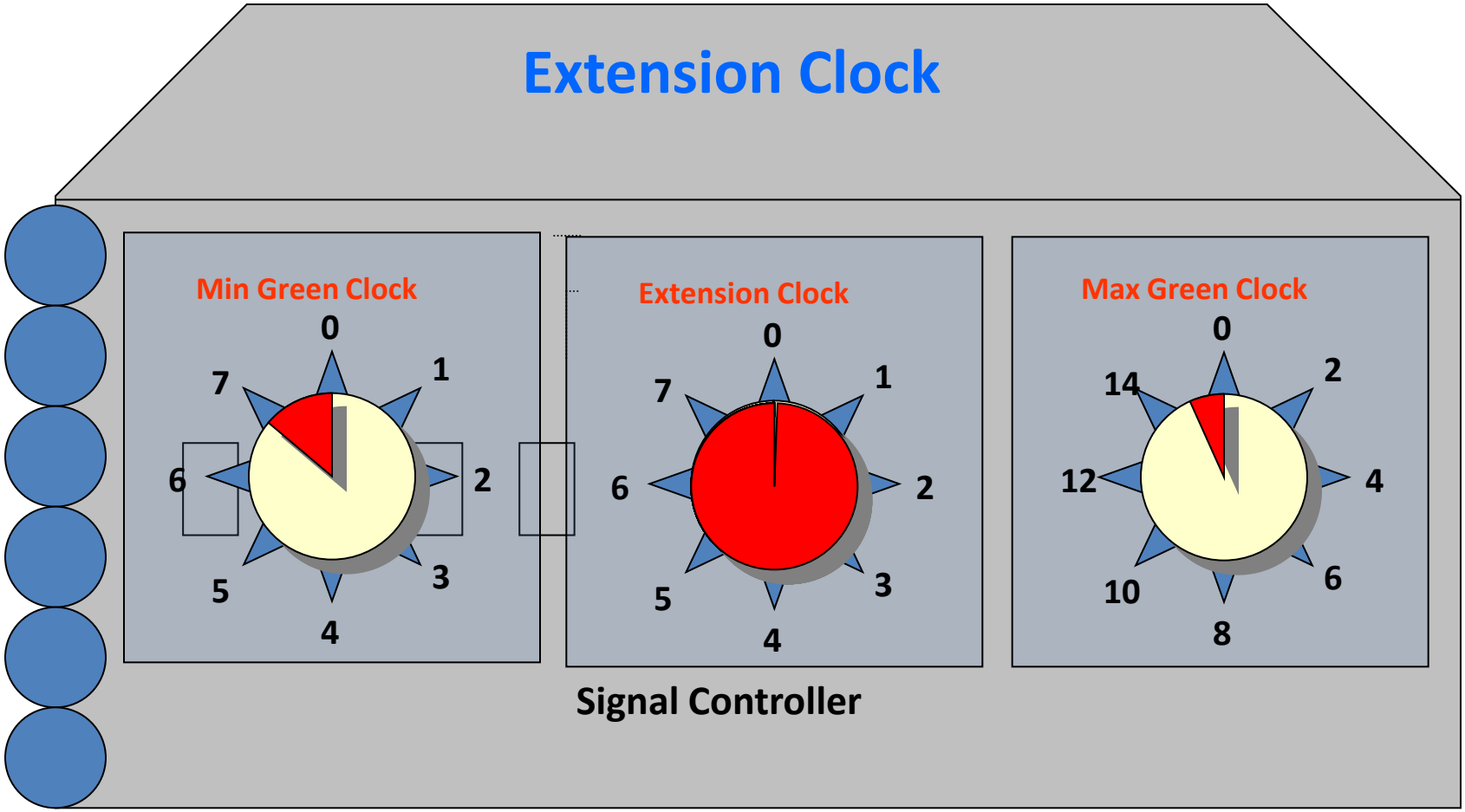
Individual (Each Phase) Control Elements of a Dual Ring Controller



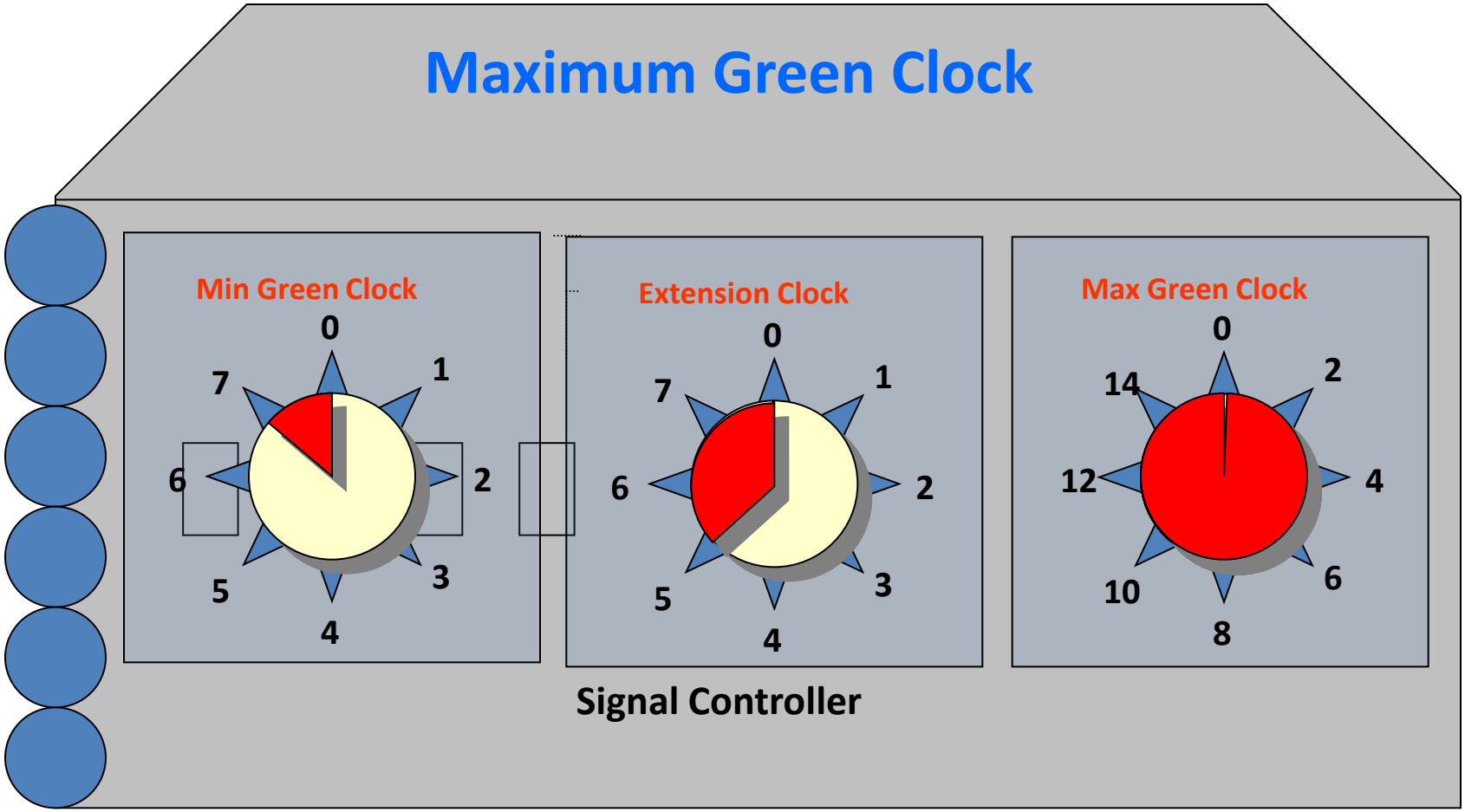
Individual (Each Phase) Control Elements of a Dual Ring Controller



Individual (Each Phase) Control Elements of a Dual Ring Controller

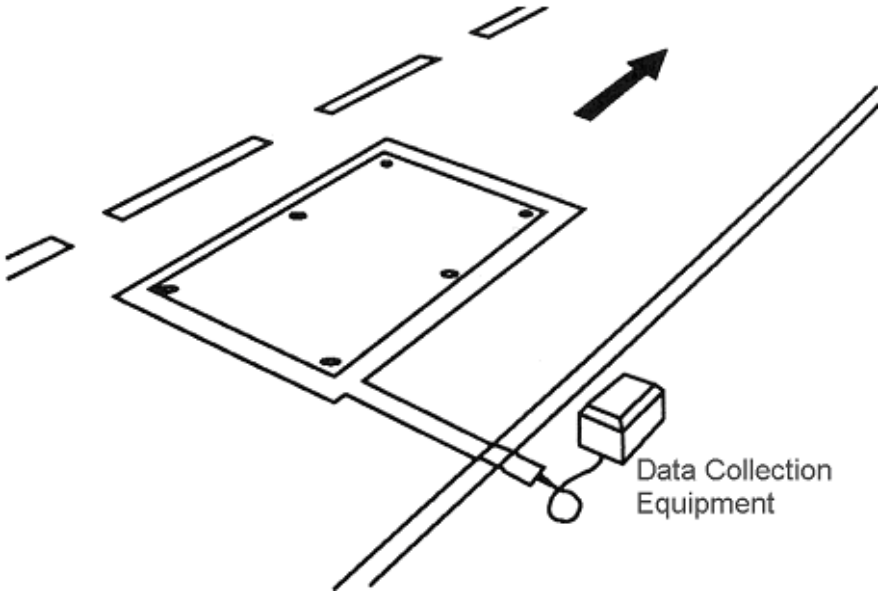


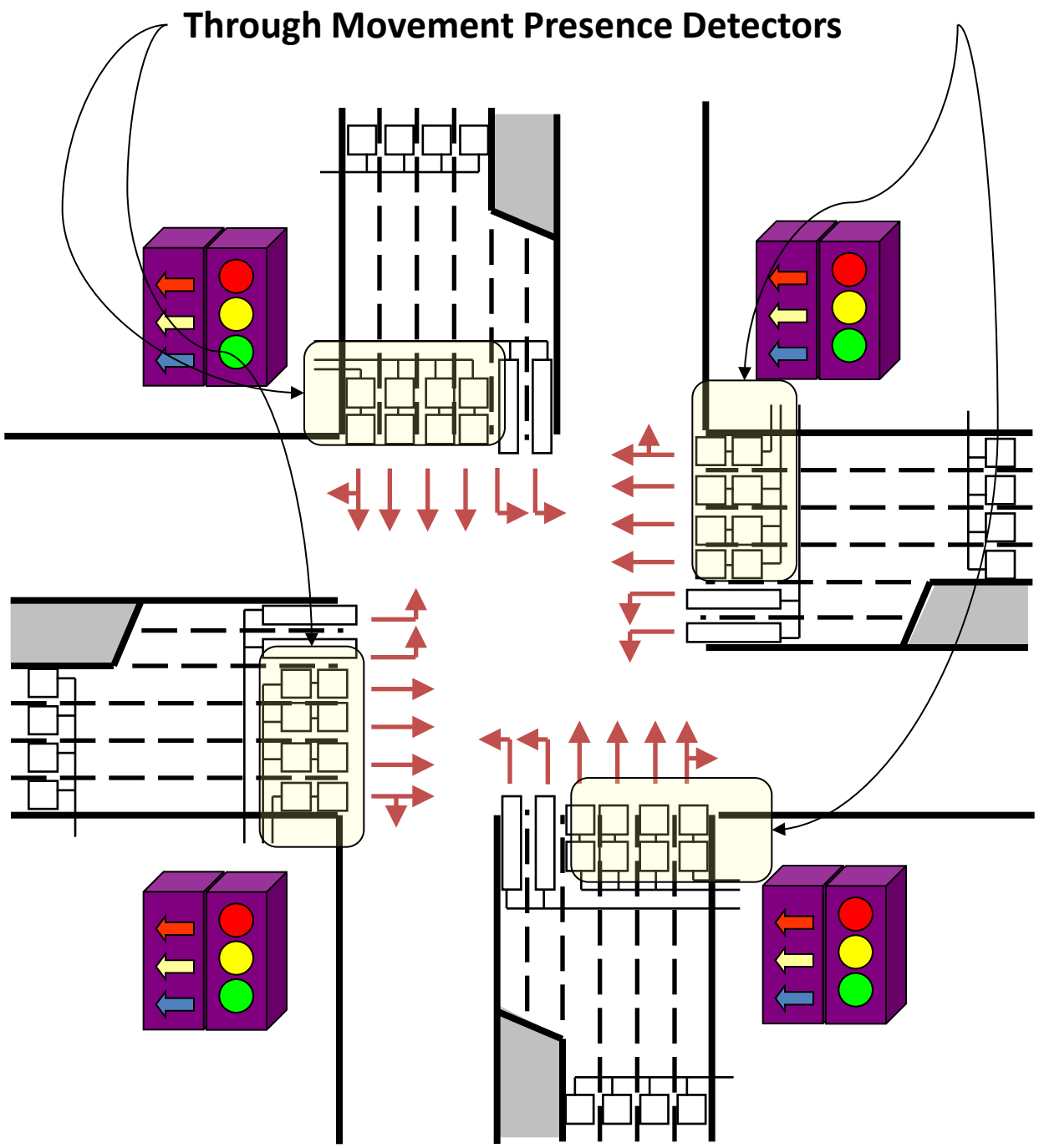
Individual (Each Phase) Control Elements of a Dual Ring Controller



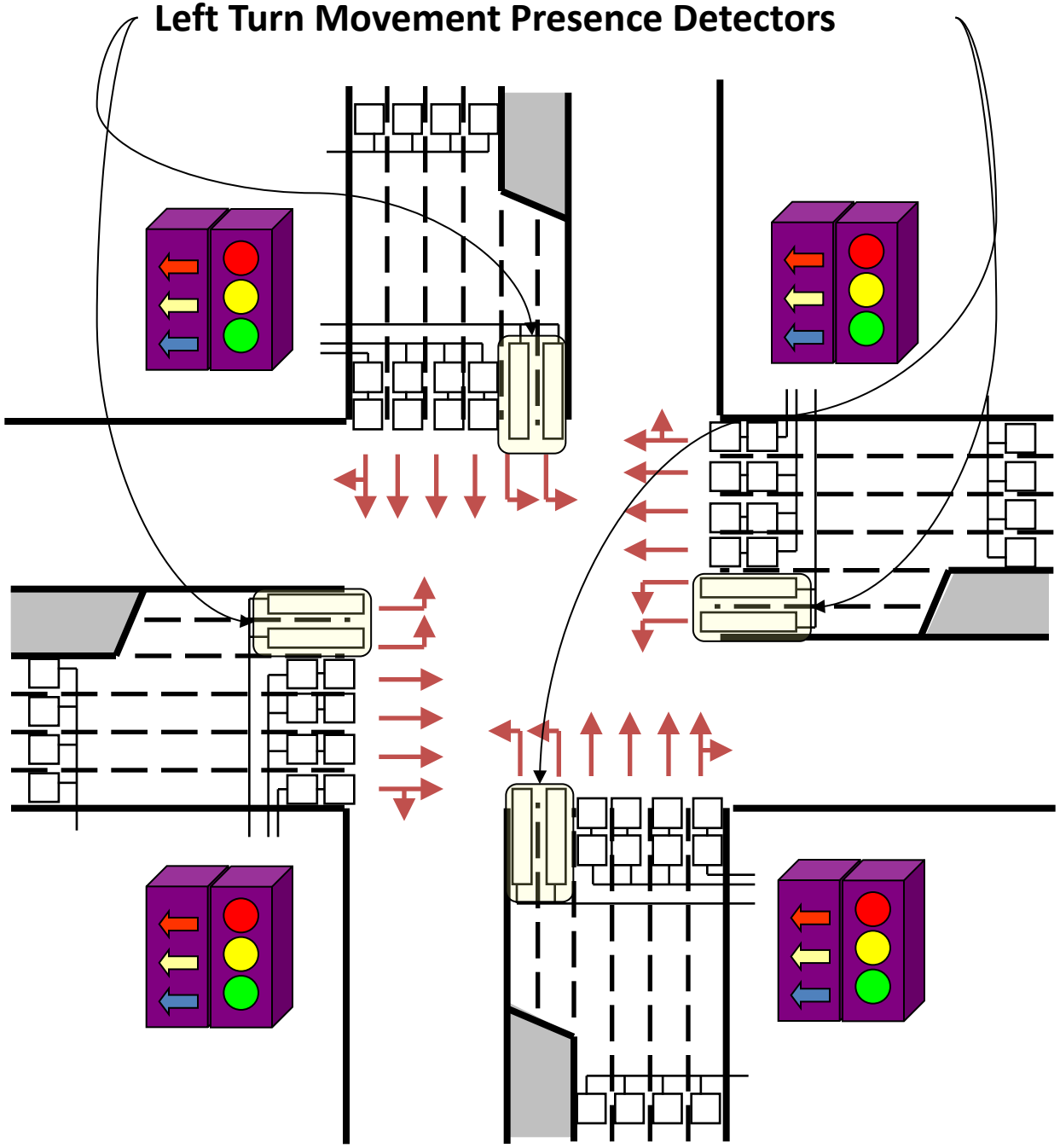
Individual (Each Phase) Control Elements of a Dual Ring Controller

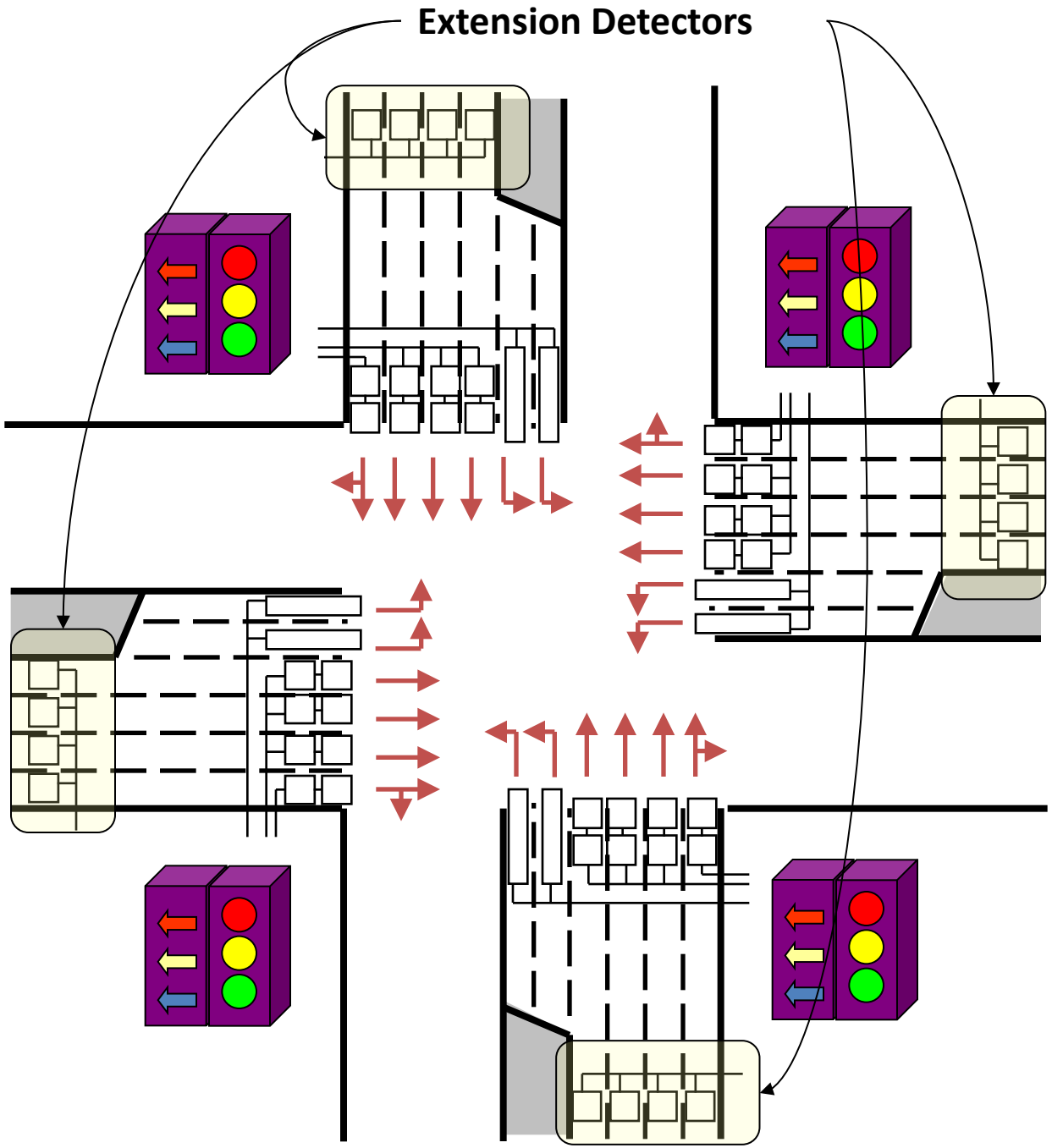
Loop detector

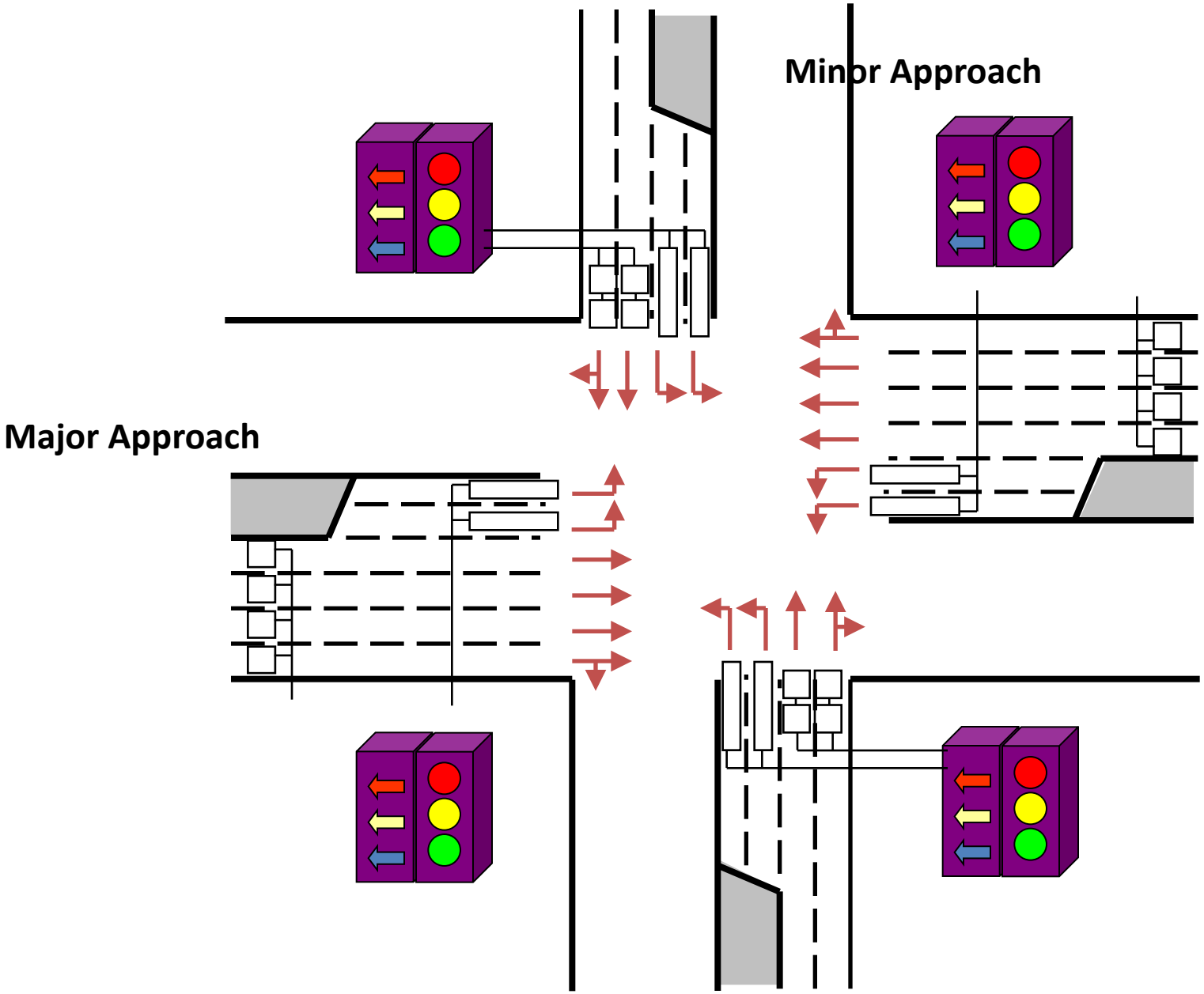



Through Movement Presence Detectors

Left Turn Movement Presence Detectors

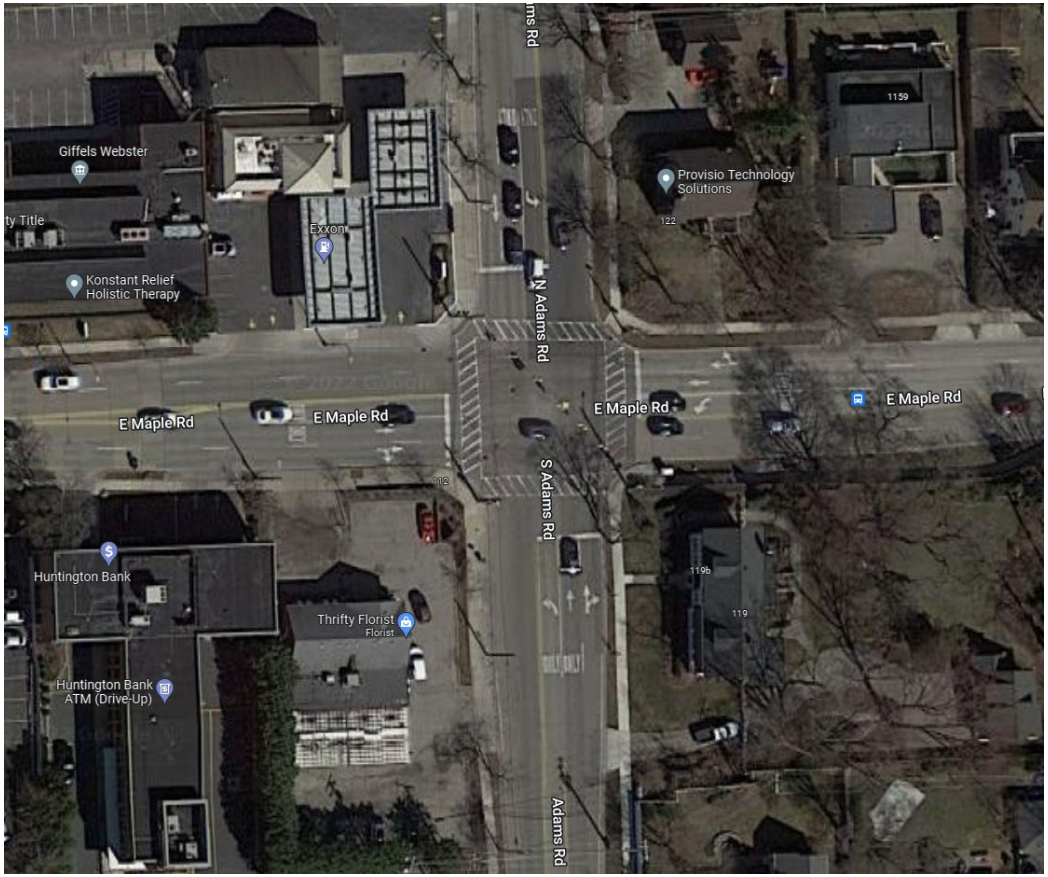



Extension Detectors

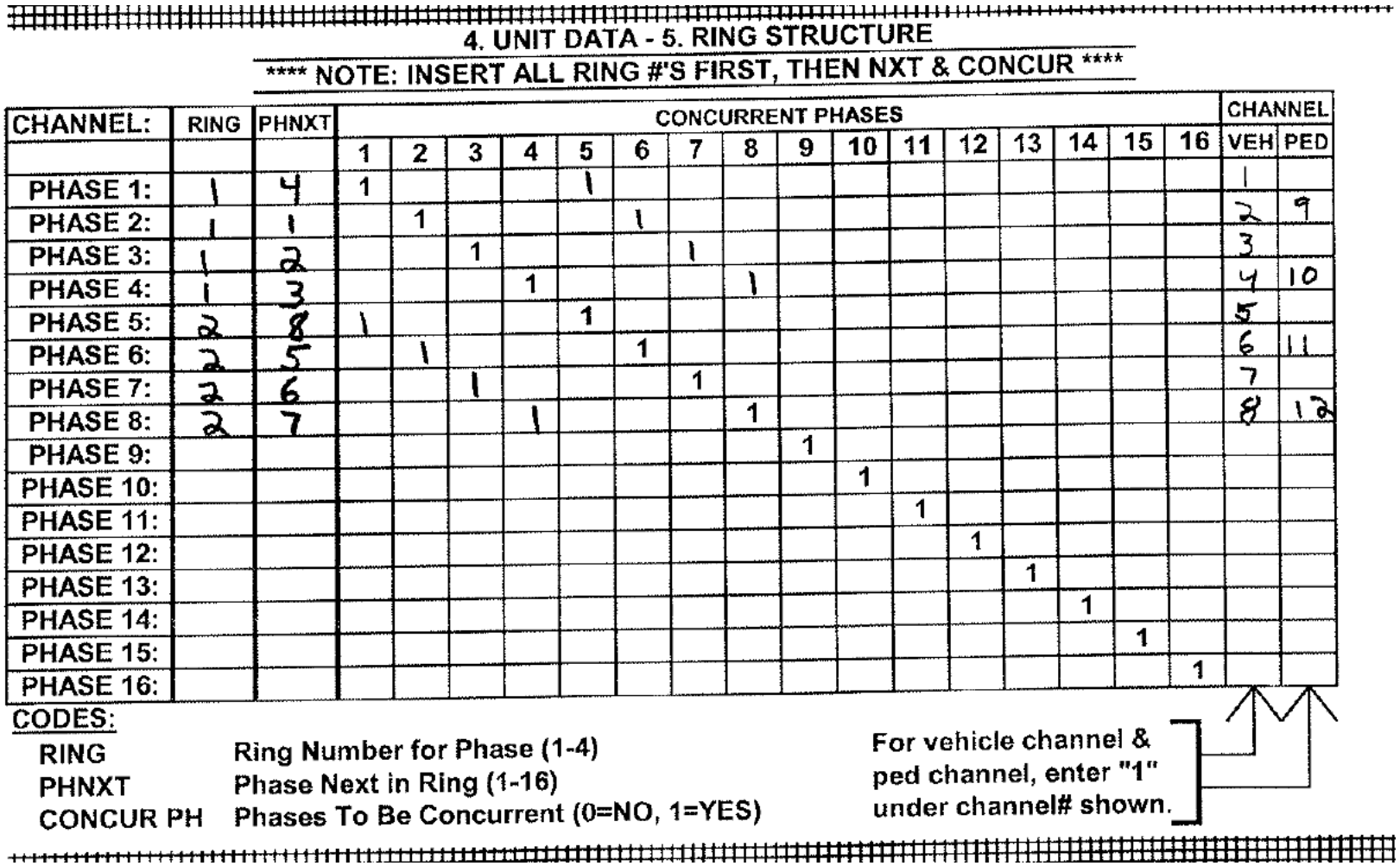

Minor Approach
Major Approach

Birmingham Signal Order

- Adams & Maple Road, City of Birmingham



Phase Structure



4. UNIT DATA - 5. RING STRUCTURE

**** NOTE: INSERT ALL RING #'S FIRST, THEN NXT & CONCUR ****

CHANNEL:	RING	PHNXT	CONCURRENT PHASES															CHANNEL	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	VEH	PED
PHASE 1:	1	4	1				1												1	
PHASE 2:	1	1		1				1											2	9
PHASE 3:	1	2			1				1										3	
PHASE 4:	1	3				1				1									4	10
PHASE 5:	2	8	1				1												5	
PHASE 6:	2	5		1				1											6	11
PHASE 7:	2	6			1				1										7	
PHASE 8:	2	7				1				1									8	12
PHASE 9:											1									
PHASE 10:												1								
PHASE 11:													1							
PHASE 12:														1						
PHASE 13:															1					
PHASE 14:																1				
PHASE 15:																	1			
PHASE 16:																		1		

CODES:

RING	Ring Number for Phase (1-4)
PHNXT	Phase Next in Ring (1-16)
CONCUR PH	Phases To Be Concurrent (0=NO, 1=YES)

For vehicle channel & ped channel, enter "1" under channel# shown.

Ring-and-Barrier Diagram

2	1	4	3
6	5	8	7

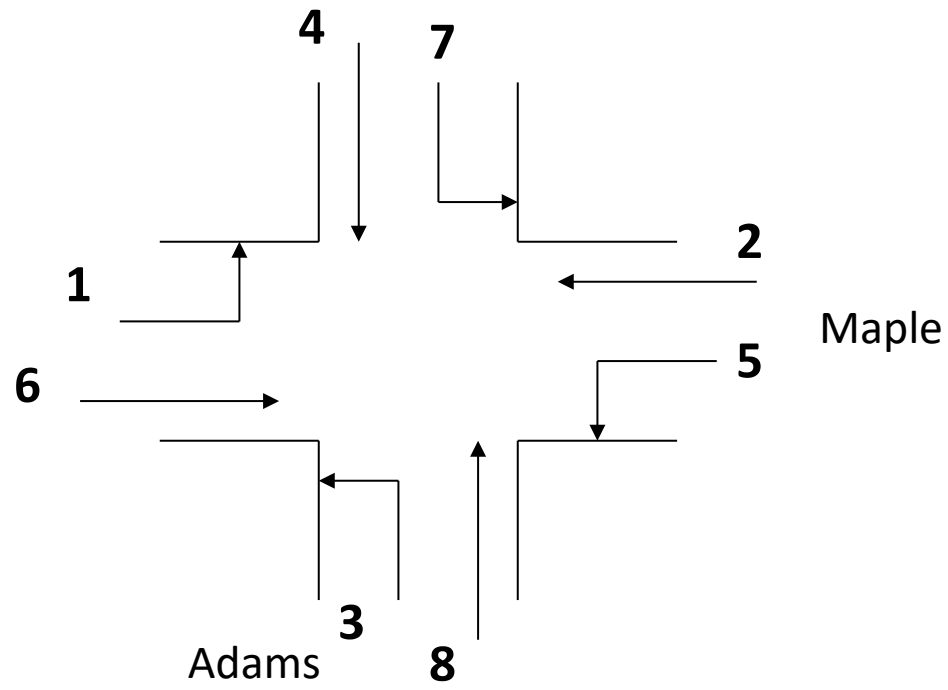
Phase-Movement Mapping

SIGNAL PHASING

PHASE#	ROAD	PHASE	LOAD SW	FLASH
1	EB Maple LT	CL	1	R
2	WB Maple	A	2	R
3	NB Adams LT	DL	3	R
4	SB Adams	B	4	R
5	WB Maple LT	AL	5	R
6	EB Maple	C	6	R
7	SB Adams LT	BL	7	R
8	NB Adams	D	8	R
OLA				
OLB				
OLC				
OLD				
1PED				
2PED	Maple N Leg PED	WA	9	
3PED				
4PED	Adams W Leg PED	WB	10	
5PED				
6PED	Maple S Leg PED	WC	11	
7PED				
8PED	Adams N Leg PED	WD	12	

Ring-and-Barrier Diagram

2	1	4	3
6	5	8	7



Phase Data

3. PHASE DATA - 1. BASIC TIMINGS

Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	RANGE
Minimum Green	5	10	5	5	5	10	5	5									00-99
Passage																	0.0-9.9
Maximum #1	8	31	8	23	8	31	8	23									000-999
Maximum #2																	000-999
Yellow Clearance	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5									3.0-9.9
Red Clearance	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5									0.0-9.9

Page 1

ROAD COMMISSION FOR OAKLAND COUNTY, WATERFORD, MICHIGAN
PROGRAM LOG FOR EAGLE SIGNAL CONTROLLER - MOD 52 EPAC

3. PHASE DATA - 3. PEDESTRIAN TIMINGS

Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	RANGE (SEC)
Walk		7		7		7		7									00-99
Pedest Clearance		13		13		13		13									00-99
Flashing Walk																	
Extend Ped Clear		0		0		0		0									(0-no, 1-Y+R, 2-Y)
Act Rest in Walk																	

Time of Day Plans

6. TIME BASE DATA - 3. TRAFFIC EVENTS

PRO DAY	TIME H H : M M	COORD PATRN		MAX 2 PHASE #S									OMIT PHASE #S							
* * *	* * * * *	D / S / O		*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*
01	00 : 00	1 / 1 / 1																		
02	00 : 00	1 / 1 / 1																		
02	07 : 00	2 / 1 / 1																		
02	10 : 00	1 / 1 / 1																		
02	15 : 00	3 / 1 / 1																		
02	19 : 00	1 / 1 / 1																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		
	:	/ /																		

REFERENCE DATA
PRO DAY = 01 - 99
(Program day)

HH:MM = 24 Hour clock

PATTERN: (D/S/O)
FLASH =5/5/
FREE =0/0/4

MAX2 & OMITS:
Call free, set pattern to 0/0/0.

D = DIAL #
S = SPLIT #
0 = OFFSET #

Cycle, Split, and Offsets

5. COORDINATION DATA - 3. DIAL/SPLIT DATA

LEVEL 2

DIAL 1 / SPLIT 1 CYCLE LENGTH: 90

PHASE	1	2	3	4	5	6	7	8
TIME	13	38	12	27	13	38	12	27
MODE	3	1	3	7	3	1	3	7

DIAL 1 / SPLIT 2 CYCLE LENGTH:

PHASE	1	2	3	4	5	6	7	8
TIME								
MODE								

DIAL 1 / SPLIT 3 CYCLE LENGTH:

PHASE	1	2	3	4	5	6	7	8
TIME								
MODE								

DIAL 1 / SPLIT 4 CYCLE LENGTH:

PHASE	1	2	3	4	5	6	7	8
TIME								
MODE								

LEVEL 1

OFFSET	1	2	3
TIME	37		
SEQUENCE			
RING 2 LAG			
RING 3 LAG			
RING 4 LAG			
OFFSET	1	2	3
TIME			
SEQUENCE			
RING 2 LAG			
RING 3 LAG			
RING 4 LAG			
OFFSET	1	2	3
TIME			
SEQUENCE			
RING 2 LAG			
RING 3 LAG			
RING 4 LAG			
OFFSET	1	2	3
TIME			
SEQUENCE			
RING 2 LAG			
RING 3 LAG			
RING 4 LAG			

Readings

- Signal Timing Manual (2nd Edition): Chapter 3, 4, 5