2.2.1 Conventional Diamond Interchange

A conventional diamond interchange is an at-grade interchange that has two closely spaced intersections of an arterial with a one-way pair of frontage roads. Figure 1 illustrates an example diamond interchange with signalized control.

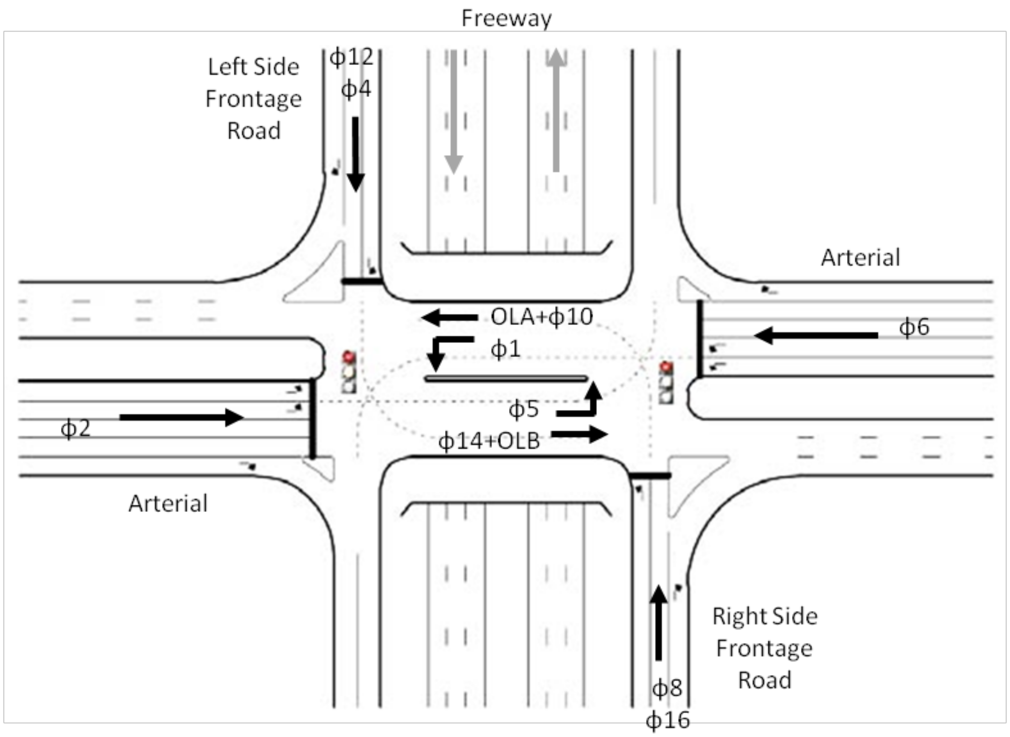
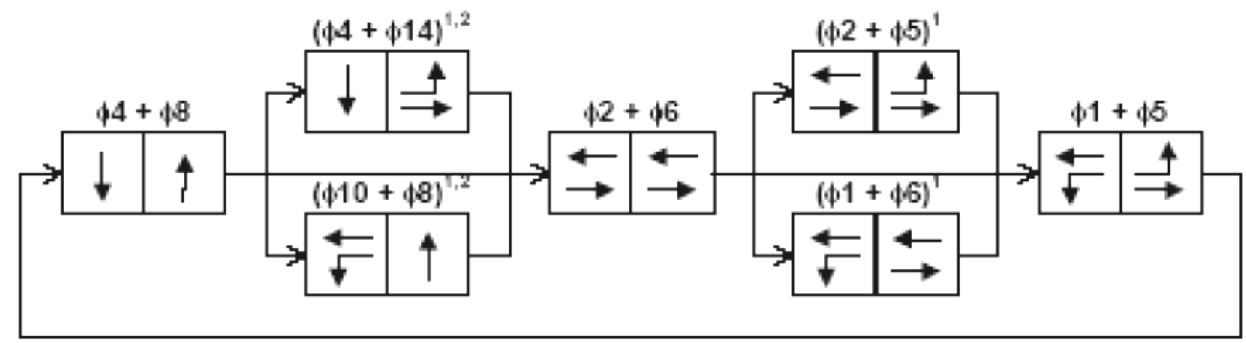
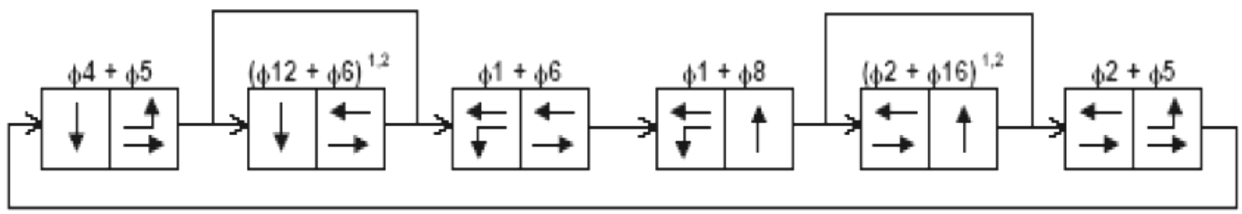


Figure 1. Conventional diamond interchange

Signal control at conventional diamond interchanges often adopts the Three-Phase operation or the Four-Phase operation. Figure 2 shows the typical phase sequence for each of the two operation methods.



a. Three-Phase Operation Phase Sequence



b. Four-Phase Operation Phase Sequence

Note:
1. Operational overlap interval;
2. 16-phase controller required.

Figure 2. Typical Signal Operations at Conventional Diamond Interchanges

The Three-phase operation services external through movements simultaneously (ϕ2+ϕ6 or ϕ4+ϕ8) without having to be interrupted by interior left turns (ϕ1 or ϕ5). The Three-Phase operation is ideal for wide interchanges (long distance between the two intersections) in rural areas with light overall traffic and heavy through movements.

The Four-Phase operation runs each exterior movement independently (ϕ2, ϕ6, ϕ4, or ϕ8) and services interior movements in concurrent external phases efficiently. This operation aims to provide progression for all movements entering the interchange to minimize stops inside the interchange. The Four-Phase operation is most effective at tight urban diamond interchanges (intersection distance up to 400 ft) with heavy turning movements.

Simulation of signal operation at conventional diamond interchanges follows the general procedures provided by the FHWA Guidelines [1] in coding geometry and traffic information. This section demonstrates signal controller settings to realize Three-Phase and Four-Phase operations with two example models developed using PTV Vissim 8.00. The models can be found in the "Diamond_3-Phase" and "Diamond_4-Phase" VISSIM example folders.

[1] Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software

Example of Three-Phase Operation

The "Diamond_3-Phase" model is developed for a rural diamond interchange with intersection spacing about 470 ft. The total traffic entering the interchange is less than 1000 vph during the peak hour. The interchange operates a Three-Phase control with a cycle length of 100 sec. The arterial external movements ϕ2 and ϕ6 are coordinated, and the frontage road movements ϕ4 and ϕ8 are conditional services. The interior left turns ϕ1 and ϕ5 lead the opposing arterial through movements ϕ2 and ϕ6, respectively. Floating force off is used to provide maximum capacity for arterial movements. Phases ϕ3 and ϕ7 are reserved as optional phases for future usage. Figure 3 shows the Base Timing settings in the RBC signal controller and the generated ring barrier diagram for the Three-Phase operation.

Basic

SG Number	1	2	3	4	5	6	7	8
SG Name	SBLT	NBTR		EBTR	NBLT	SBTR		WB...
Min Green	5	10		10	5	10		7
Veh Extension	1	1		1	1	2		1
Max 1	15	40		30	20	40		30
Yellow	4	4	4	3.5	4	4	4	3.5
Red Clearance	1	1	1	1	1	1	1	1
Start Up	☐	☑	☐	☐	☐	☑	☐	☐

Advanced

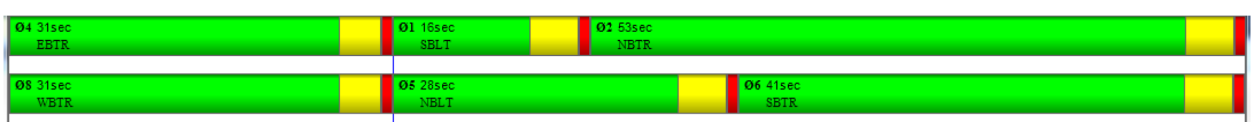
Signal Group:	1	2	3	4	5	6	7	8
Cond Service	☐	☐	☐	☑	☐	☐	☐	☑

Pattern 1

Signal Group:	1	2	3	4	5	6	7	8
Splits	16	53		31	28	41		31
Min Green	11	16	6	16	11	16	6	13
Transition Max	19	63		37	33	49		37
Floating Force Off	☑	☐	☐	☑	☑	☐	☐	☑
Coordinated	☐	☑	☐	☐	☐	☑	☐	☐

Sequence

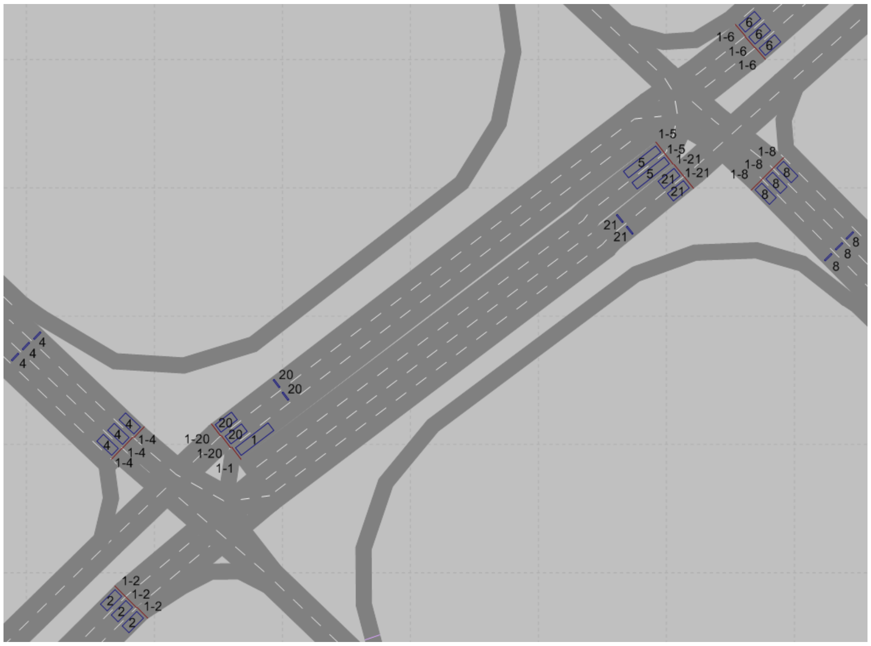
Ring 1			4	1	2
Ring 2			8	5	6



Note: Settings not shown are left blank.

Figure 3. Vissim RBC Signal Controller Base Timing Settings for the Diamond_3-Phase Example

Note that the interior through movements run as overlaps of the concurrent interior left turns and the opposing through (ϕ1+ ϕ2 for SB interior through, ϕ5+ϕ6 for NB interior through). This is set by assigning detector #20 and #21 to call ϕ1+ ϕ2 and ϕ5+ϕ6, respectively, and placing these detectors on the corresponding interior through lanes (Detector PortNo #20 for southbound and PortNo #21 for northbound interior through lanes). Accordingly, two overlap signal groups #1-20 and #1-21 are assigned for the two interior through movements, and signal heads using the two overlap signal groups are placed at the stop lines of these interior through lanes. Figure 4 shows the relevant settings in the RBC signal controller to realize the Three-Phase operation.



Note: notation numbers with a dash indicate signal group IDs and numbers without a dash are detector IDs.

Figure 4a. Assignment of Signal Groups and Detectors for South Intersection

Overlaps

Overlap SG	20	21													
Yellow Clearance	4	4													
Red Clearance	1	1													
Parent	1,2	5,6													

Veh Detectors

Detector Number	1	2	4	5	6	8	20	21
Detector Mode	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect
Added Initial Mode	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled
Call	1	2	4	5	6	8	1,2	5,6
Extend SGs	1	2	4	5	6	8	1,2	5,6

Note: Settings not shown are left blank.

Figure 4b. Overlap and Detector Settings for RBC Signal Controller

Figure 4. Overlap Signal Group and Detector Settings for Interior Movements in Diamond_3-Phase Example

Example of Four-Phase Operation

The "Diamond_4-Phase" model is developed for a tight urban diamond interchange with intersection spacing about 330 ft. The total traffic entering the interchange is close to 8000 vph during the peak hour. The interchange operates a Four-Phase control with a cycle length of 135 sec. Arterial eastbound movements ϕ6 and ϕ1 are coordinated. Interior left turns lead the opposing through. Due to heavy frontage right turn demand, ϕ3 and ϕ7, equivalent to ϕ12 and ϕ16 in Figure 1, respectively, are used to add additional capacity. Figure 5 shows the Base Timing settings in the RBC signal controller.

Basic

SG Number	1	2	3	4	5	6	7	8								
SG Name	EBLT	WB...	NBRT	NBT	WB...	EBTR	SBRT	SBT								
Min Green	3	7	3	3	3	7	3	3								
Veh Extension	2	2		2	2	2		2								
Max 1	20	45		25	20	35		25								
Yellow	4	4	4.5	4.5	4	4	4.5	4.5								
Red Clearance	1.5	1.5	2	2	1.5	1.5	2	2								
Min Recall	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	☐	☐	☐	☐	☐
Max Recall	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dual Entry	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Advanced

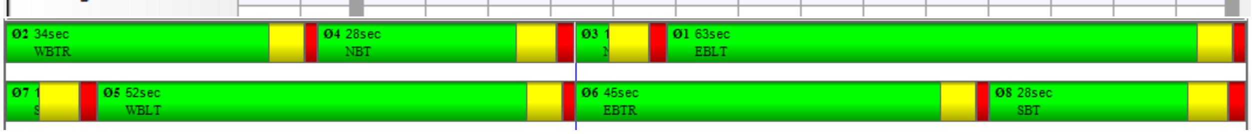
Signal Group:	1	2	3	4	5	6	7	8								
Max 2	25	65		45	25	55		35								
Red Revert	4	4	4	4	4	4	4	4								
Min Gap	1	1.5		1.5	1	1.5		1.5								
Reduce After	5	10		10	5	10		10								
Time To Reduce	5	5		5	5	5		5								

Pattern 1

Signal Group:	1	2	3	4	5	6	7	8								
Splits	63	34	10	28	52	45	10	28								
Splits Extension	20															
Perm Min Green	8	12		8	8	12		8								
Transition Max	75	40	12	33	62	54	12	33								
Max 2	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Coordinated	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Min Recall	☐	☐	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐
Max Recall	☐	☑	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Sequence

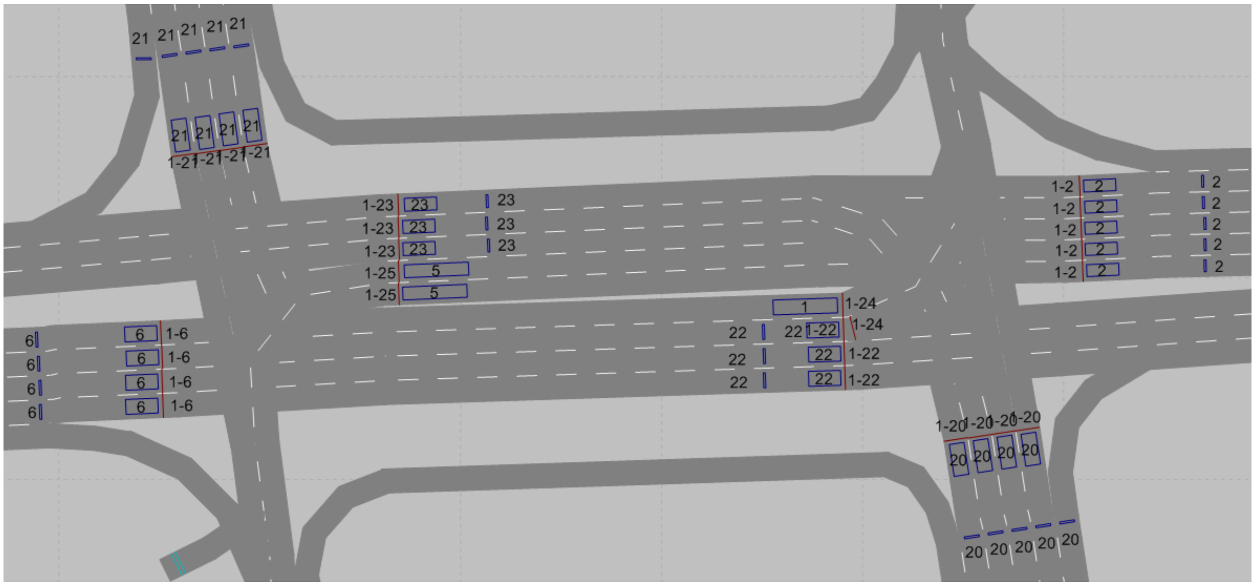
Ring 1	2	4	3	1												
Ring 2	7	5	6	8												



Note: Settings not shown are left blank.

Figure 5. Vissim RBC Signal Controller Base Timing Settings for the Diamond_4-Phase Example

The frontage road movements run as overlap of the through and right turn phases (ϕ4+ϕ3 or ϕ8+ϕ7). The interior left turn signal run as the overlap of interior left turns and the concurrent frontage right turns (ϕ1+ϕ3 or ϕ5+ϕ7). Similar to Three-Phase operation, the interior through signals run as overlaps of the opposing through and interior left turns (ϕ2+ϕ1 or ϕ6+ϕ5). The method of numbering and placement of overlap signal groups and detectors are similar to that of the Diamond_3-Phase example and is shown in Figure 6.



Note: notation numbers with a dash indicate signal group IDs; numbers without a dash are detector IDs.

Figure 6a. Assignment of Signal Groups and Detectors for South Intersection

Overlaps

Overlap SG	20	21	22	23	24	25										
Parent	3,4	7,8	1,2	5,6	1,3	5,7										

Veh Detectors

Detector Number	1	2	5	6	20	21	22	23
Detector Mode	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect	No Disconnect
Added Initial Mode	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled	Disabled
Call	1	2	5	6	3,4	7,8	1,2	5,6
Extend SGs	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3

Note: Settings not shown are left blank.

Figure 6b. Overlap and Detector Settings for RBC Signal Controller

Figure 6. Overlap Signal Group and Detector Settings for Interior Movements in Diamond_4-Phase Example

Note that the eastbound interior left turns use one exclusive left turn lane and one shared lane in this example. Two signal heads are used for this shared left turn lane: one left turn signal head (Overlap SG #1-24) is placed on the left turn lane connector, and one through signal head (Overlap SG #1-22) is placed on the link upstream of the left turn connector. An alternative way of modeling this is to assign both left turn and through signal groups (Overlap SG #1-22 OR #1-24) to the shared lane (signal head placed on the link, not on the connector).