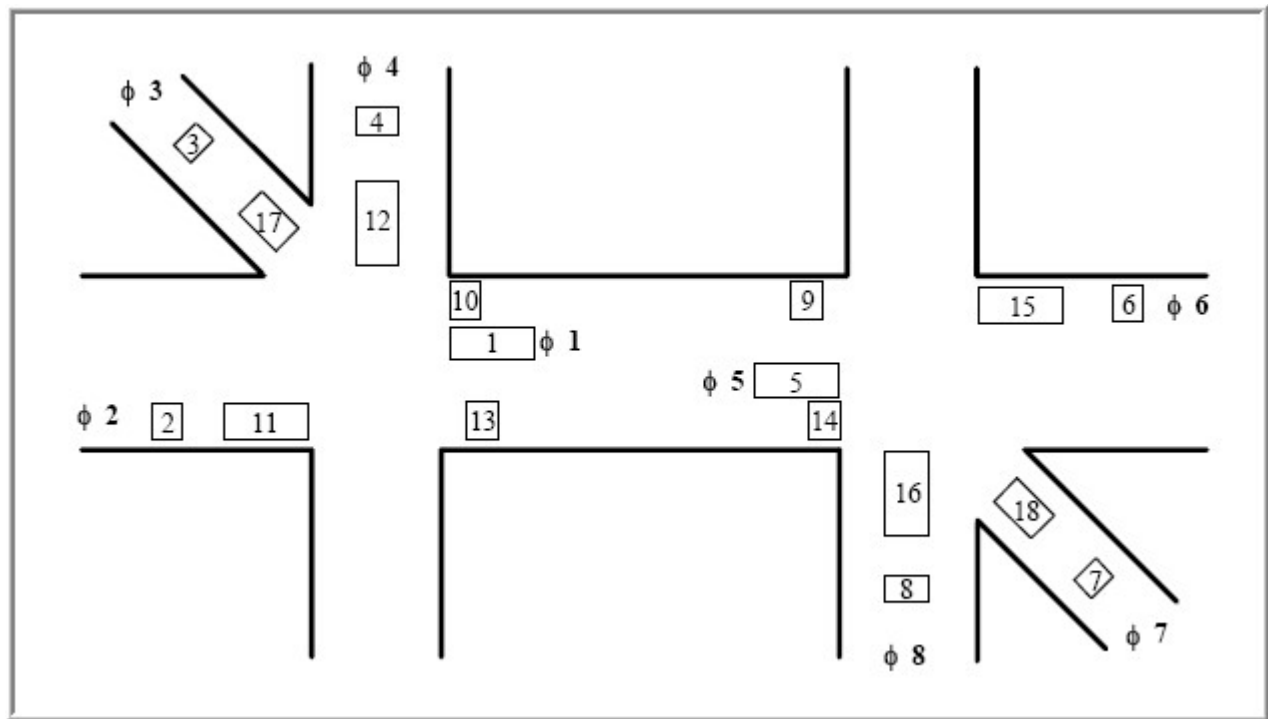




Operations Manual

For

Texas Diamond Controllers



February 2021

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1 Diamond Modes

1.1 DIAMOND Mode Default Programming

Diamond Operation conforms to the State of Texas Diamond Controller Specification. Initializing a controller as a DIAMOND under MM->8->4:

- ☐ sets the Phase Mode unit parameter to DIAM (MM->1->2->1)
- ☐ sets the Diamond Mode unit parameter to 4Ø (4-phase operation) – this parameter may be changed to 3Ø (3-phase) or SEP (separate intersection modes) to set the default free operation of the diamond
- ☐ programs several defaults in the controller database needed to conform to the Texas diamond specification

1.1.1 Default Overlaps for DIAMOND Operation

Overlap	Phase:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A		1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
B		0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
C		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I		1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
J		0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
K		0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
L		0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
M		0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
N		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
O		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

All overlap clearances are initialized as 3.5 seconds of yellow and 1.5 seconds of red as a precaution. However, during DIAMOND operation, overlaps use the clearance times of their parent phases.

DIAMOND FYA PROGRAMMING NOTES – Program overlaps C and E as shown below. These are to be modified by opposing direction, (i.e. 2, 6) and the Channel 1 and 5 should be mapped to these overlaps instead of 9 and 12. Then follow programming guide for FYA for your controller type.

Overlap	Phase:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
C		1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
E		0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0

1.1.2 Default Channel Assignments

Initializing a controller as a DIAMOND automatically programs these channel assignments under MM->1->3->1:

Channel #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ø / Olp#	9 (I)	2	10 (J)	11 (K)	12 (L)	6	13 (M)	14 (N)	1 (A)	2 (B)	3 (C)	4 (D)	2	4	6	8
Type	OLP	VEH	OLP	OLP	OLP	VEH	OLP	OLP	OLP	OLP	OLP	OLP	PED	PED	PED	PED

1.1.3 Dual Entry and Conditional Service Defaults

When a controller is initialized as a DIAMOND, phases 2, 6, 9, 10, 11 12, 13, 14, 15, 16 are automatically programmed as dual entry phases. If the controller is operating as a 4-phase or separate intersection diamond, phases 4 and 8 cannot use conditional service phase. However, phases 4 and 8 will be automatically programmed for conditional service phases under 3-phase diamond operation.

1.2 Diamond Operating Modes – (3Ø, 4Ø and Sep)

The Diamond Operating Mode selected depends on several factors and traffic conditions that may vary by time-of-day. The Cubic | Trafficware ATMS controllers allow the Diamond Operating Mode to be varied by pattern providing flexibility to managing the traffic demands at diamond interchanges.

In general, 4-phase operation is typically used when the spacing between the intersections is less than 200 ft. or the interior left-turns (phases 1 and 5 in the figure below) are heavy when compared with the other movements. 3-phase operation is typically used when the intersections are widely spaced (greater than 300-400 ft.) and the demand for the interior left-turn movements is minor.

The same phase assignments below apply to the 3-phase, 4-phase and separate intersection Diamond Modes.

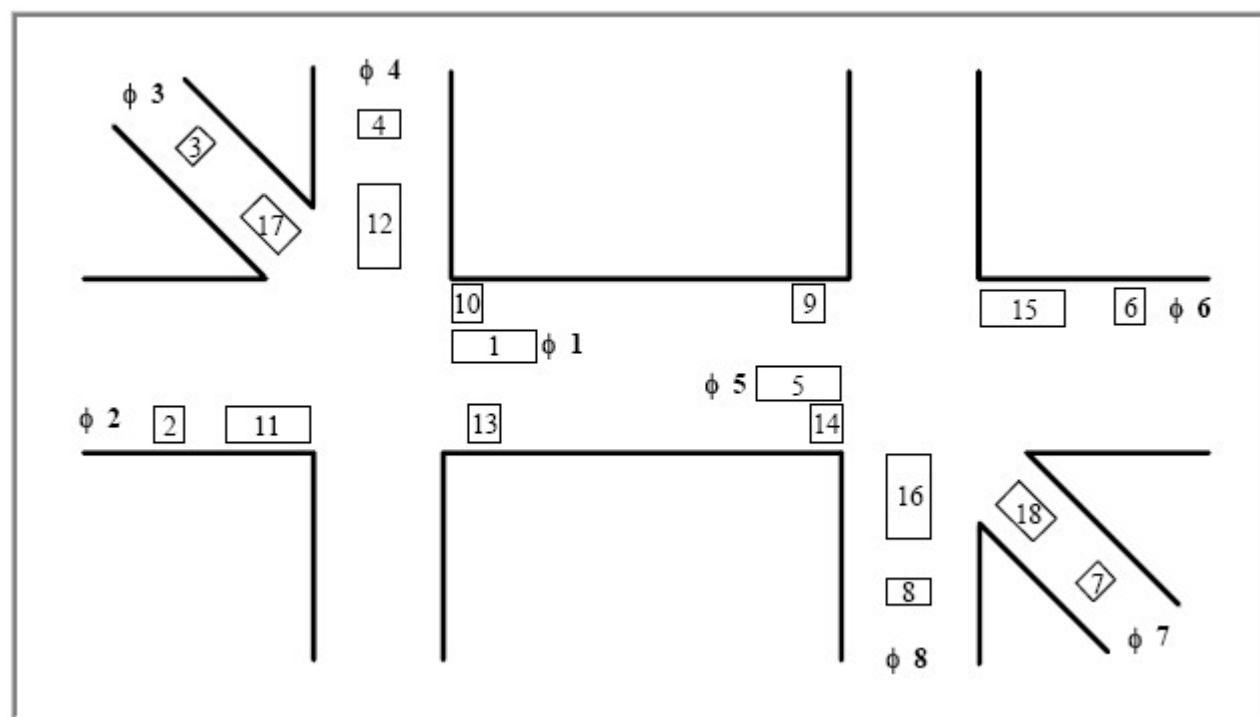
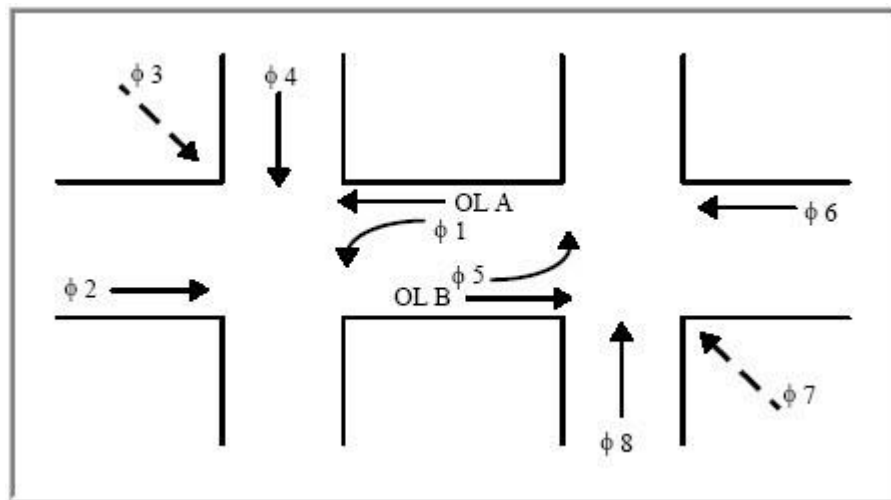


Figure dia_4p_a: Texas Diamond Operation

2 Four Phase Diamond Operation

Four Phase Diamond Operation drives the signal indications for two “highly coupled” intersections at a diamond interchange. The term “highly coupled” implies that the phases serviced at each side of the interchange directly control how phases are serviced at the other side of the interchange. This “coupling” insures that queues do not extend from one side of the interchange through the upstream intersection. This contrasts greatly with Separate Intersection Diamond Operation that allows phases on either side of the interchange to service independently.

The sequence table (dia_4p_2) for 4-phase diamond operation is shown below.

Texas Std ID	1725	1825	25	35	45	L-R	N.A.	3516	4516	16	17	18	R-L	N.A.
Ring 1	2		3	4	9	10	11	12	1					
Traffic Std ID														
Ring 2	15	16	5				6		7	8	13	14		

dia_4p_2:Four Phase Diamond Sequence Table

When a controller is initialized as a DIAMOND (MM->8->4), “Seq 97” and “D4Ø” are displayed in the right hand corner of the Phase Timing Status screen. Only sequences 1-16 may be viewed or edited under MM->1->2->4, but if you could view sequence 97 (Seq 97) under MM->1->2->4, the sequence table would appear as follows:

Seq#	Ring	<u>Sequence of Phases</u>									
97	1	2	3	4	9	10	11	12	1		
97	2	15	16	5	6	7	8	13	14		
97	3	Ø Concurrency Barriers									
97	4										

Default Sequence 97 - Used With the Four Phase Diamond (D4Ø)

Note that the Sequence Table provides the order of phases in each ring and does not imply barriers between the phases. Therefore, programming phase 9 in ring 1 directly over phase 6 in ring 2 does not imply that these phases may be concurrent. Phase concurrency (barrier programming) is determined by the active Concurrency Table.

Also note that the active Concurrency Table under DIAMOND operation does not reflect programming under MM->1->1->4. The active Concurrency Table is based on the diamond mode currently in effect and cannot be edited through the controller menu. For example, 4-phase mode enables the following concurrencies:

Phase	Ring	Concurrent Phase(s)	Phase Enabled
1	1	6-7-8-13-14	X
2	1	5-15-16	X
3	1	5	X
4	1	5	X
5	2	2-3-4-9-10	X
6	2	1-11-12	X
7	2	1	X
8	2	1	X
9	1	5	X
10	1	5	.
11	1	6	X
12	1	6	X
13	2	1	X
14	2	1	.
15	2	2	X
16	2	2	X

Figure dia_4p_1: Phase, Ring and Concurrency for a 4-Phase Diamond (D4Ø)

Default Programming Applied During 4-phase Diamond Operation

- 1) Phases 10 and 14 are omitted and dual entry is placed on phases 2 and 6.
- 2) Refer to figure dia_4p_3 to understand the limits and the different clearance intervals:
 - a. Phase 15 generates the 1725 clearance interval, which operates simultaneously with phase 2. When in this interval, phase 2 timing will not begin until this interval is complete.
 - b. Phase 16 generates the 1825 clearance interval, which operates simultaneously with phase 2. When in this interval, phase 2 timing will not begin until this interval is complete.
 - c. Phase 11 generates the 3516 clearance interval, which operates simultaneously with phase 6. When in this interval, phase 6 timing will not begin until this interval is complete.
 - d. Phase 9 performs the Left to Right Clearance (phase 1-5) which is inserted when a skip in the standard sequence occur from the right side to the left side of the diamond.

25-15-16, 25-15-17, 25-15-18, 35-15-17, 35-15-18, 45-15-17 & 45-15-18

- e. Phase 13 performs the Right to Left Clearance (phase 1-5) which is inserted when a skip in the standard sequence occur from the left side to the right side of the diamond.

16-15-25, 16-15-35, 16-15-45, 17-15-35, 15-15-45, 18-15-13 & 18-15-45

- 3) The standard sequence for 4-phase operation is:

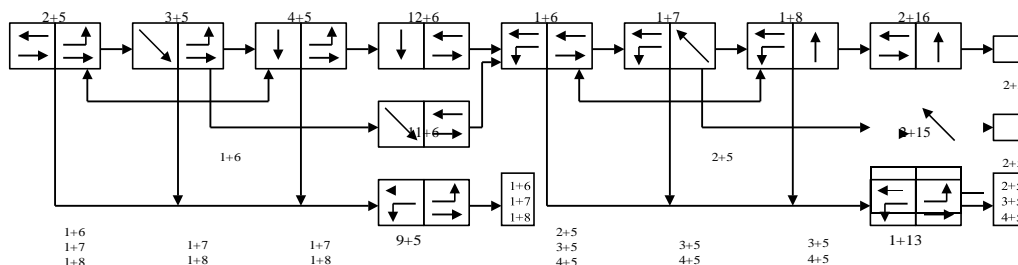


Figure dia_4p_4: Four Phase Diamond Sequence

- 4) The 4 Phase Diamond mode automatically programs the Call and Extend detector parameters as shown below. All other detector parameters must be set by the user.

Det #	Call	Switch	Extend	Options
1	0	0	0.0	Call & Ext
2	2	0	0.0	Call & Ext
3	3	* 11 -0	0.0	Call & Ext
4	4	* 12 -0	0.0	Call & Ext
5	0	0	0.0	Call & Ext
6	6	0	0.0	Call & Ext
7	7	* 15 -0	0.0	Call & Ext
8	8	* 16 -0	0.0	Call & Ext
9	0	0	0.0	Call & Ext
10	0	0	0.0	Call & Ext
11	2	0	0.2	Call & Ext
12	4	* 12 -0	0.2	Call & Ext
13	0	0	0.0	Call & Ext
14	0	0	0.0	Call & Ext
15	6	0	0.2	Call & Ext
16	8	* 16 -0	0.2	Call & Ext
17	3	* 11 -0	0.2	Call & Ext
18	7	* 15 -0	0.2	Call & Ext

* Change must be input by the user

Default Detector Programming for Four Phase Diamond

Programming to be Applied by the User During 4-phase Diamond Operation

To properly run a 4-phase Diamond, the User must implement the following programming:

- 1) Under MM>2>1. ForceOffMode must be set to "OTHER" and Force-Off+ must be set to "Easy"

Coordination Modes	>	Coordination Modes+	<
OpMode 3		Force-Off+ EASY	Easy Float OFF
ForceOffMode OTHER		Closed Loop ON	Auto Err Reset ON
CorrectionMode SHORT/LONG		External OFF	NTCIP Yield + 0
MaximumMode MAX_INH		Latch Sec Frc OFF	-- Leave Walk --
FlashMode CHANNEL		Stop-in-Walk ON	Before TIMED
		Walk Recycle NO_RECYCLE	After TIMED
		FreeOnSeqChg OFF	+ NoAddedInit OFF

- 2) In MM>5>1, the Switch Phases must be set to 0, as shown on the table on the previous page.
- 3) Set "Red Rest in Gap" to "ON" (MM>1>1>3) for phases 11,12,15,16.

< Options+	P.9.10.11.12.13.14.15.16
Ped Delay -	
Red Rest On Gap	. . . X X . X X
Conflicting P	0 0 0 0 0 0 0 0
Grn/Ped Delay	0 0 0 0 0 0 0 0
Omit Yel, Yel P	0 0 0 0 0 0 0 0
Ped Out/Ovrlp P	0 0 0 0 0 0 0 0
StartYel,Next P	+ 0 0 0 0 0 0 0

- 4) In the Split Tables (MM>2>7>#>1) certain phases need to be omitted if phases 2,3,4,5,6,7, and/or 8 are omitted.
 - If 3 is omitted, then 11 is to be omitted in the Split Table
 - If 4 is omitted, then 12 is to be omitted in the Split Table
 - If 7 is omitted, then 15 is to be omitted in the Split Table
 - If 8 is omitted, then 16 is to be omitted in the Split Table
 - If 2 is omitted, then 15 and 16 are to omitted in the Split Table
 - If 6 is omitted, then 11 and 12 are to omitted in the Split Table

3 Three Phase Diamond

The same phase and detector assignments below apply to the 3-phase, 4-phase and separate intersection Diamond Modes.

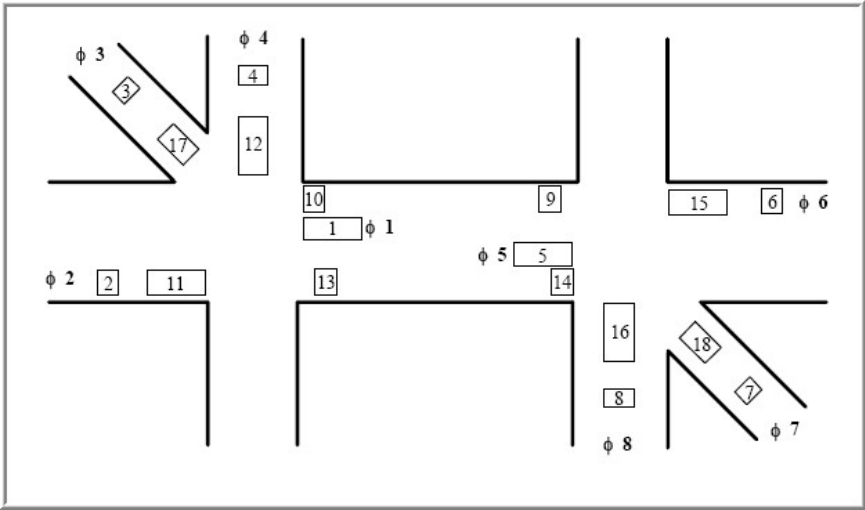


Figure dia_4p_a: Texas Diamond Operation

Texas Std ID	N.A	N.A.	15	48	15	37	26	15
Ring 1	12	11	10	4	9	3	2	1
Traffic Std ID								
Ring 2	16	15	14	8	13	7	6	5

dia_3p_2: Three Phase
Diamond Sequence
Table

When a controller is initialized as a DIAMOND (MM->8->4), the default Phase Mode is DIAM and the Diamond Mode is 4Ø (Unit Parameters, MM->1->2->1). The Diamond Mode may be changed to 3Ø for 3-phase operation. When 3-phase is active, “Seq 98” and “D3Ø” are displayed in the right hand corner of the Phase Timing Status screen. Sequence 98 cannot be edited and provides the following ring sequences for 3-phase operation:

Seq#	Ring	Sequence.of.Phases							
98	1	12	11	10	4	9	3	2	1
98	2	16	15	14	8	13	7	6	5
98	3	0	0	0	0	0	0	0	0
98	4	0	0	0	0	0	0	0	0

Default Sequence 98 - Used With the Three Phase Diamond (D3Ø)

Again, note that the Sequence Table provides the order of phases in each ring and does not imply barriers between the phases in each ring. Phase concurrency (barrier programming) is determined by the active Concurrency Table.

The active Concurrency Table under DIAMOND operation cannot be viewed under menu MM->1->1->4. The active Concurrency Table is based on the diamond mode currently in effect and cannot be edited through the controller menu. For example, 3-phase mode enables the following concurrencies:

Phase	Ring	Concurrent Phase(s)	Phase Enabled
1	1	5-6	X
2	1	5-6	X
3	1	7-13	X
4	1	8-14	X
5	2	1-2	X
6	2	1-2	X
7	2	3-9	X
8	2	4-10	X
9	1	7-13	X
10	1	8-14	X
11	1	15-16	.
12	1	15-16	.
13	2	3-9	X
14	2	4-10	X
15	2	11-12	.
16	2	11-12	.

Figure dia_3p_1: Phase, Ring and Concurrency for a 3-Phase Diamond (D3Ø)

Default Programming Applied to 3-Phase Operation

- 1) Phases 11, 12, 15, 16 are omitted by the software and dual entry is placed on phases 2, 6, 9, 10, 13, 14
- 2) Dynamic Logic is added to ease the users programming of restricted operation when certain phases are not enabled (omitted) incase the operator forgets.

If 3 is omitted, then 13 is omitted also

If 4 is omitted, then 14 is omitted

If 7 is omitted, then 9 is omitted

If 8 is omitted, then 10 is omitted

- 3) The standard sequence for 3-phase operation is:

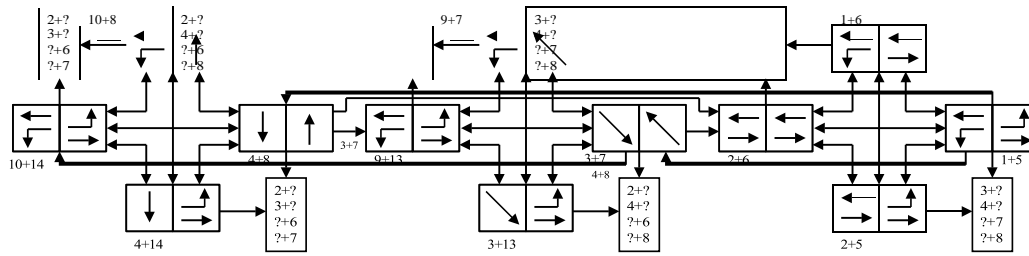


Figure dia_3p_a: Three Phase Diamond Sequence

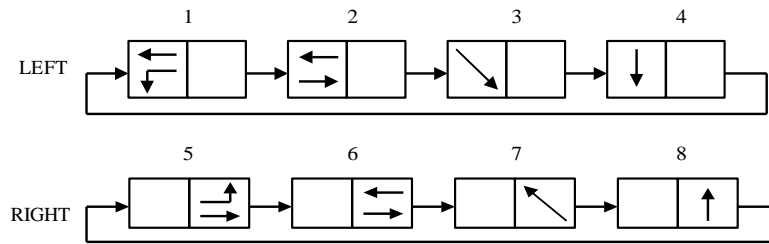
- 4) The 3 Phase Diamond mode automatically programs the Call and Extend detector parameters as shown below.
- 5) All other detector parameters are set by the user.

Det #	Call (default)	Switch	Extend (default)	Options
1	0	0	0.0	Call & Ext
2	2	0	0.0	Call & Ext
3	3	11	0.0	Call & Ext
4	4	12	0.0	Call & Ext
5	0	0	0.0	Call & Ext
6	6	0	0.0	Call & Ext
7	7	15	0.0	Call & Ext
8	8	16	0.0	Call & Ext
9	0	0	0.0	Call & Ext
10	0	0	0.0	Call & Ext
11	2	0	0.2	Call & Ext
12	4	12	0.2	Call & Ext
13	0	0	0.0	Call & Ext
14	0	0	0.0	Call & Ext
15	6	0	0.2	Call & Ext
16	8	16	0.2	Call & Ext
17	3	11	0.2	Call & Ext
18	7	15	0.2	Call & Ext

Default Detector Programming for Three Phase Diamond

4 Separate Intersection Mode

Separate Intersections Mode functions as two independent intersections operating in separate rings. Phase operation on the “left” side of the diamond interchange is completely independent of the phase operation on the “right” side of the diamond. This mode can be used in free operation when the spacing between the intersections is great enough and the traffic volumes are light enough that queue buildup between the intersections is not a concern.



dia_si_a : Separate Intersection Mode

Texas Std ID | N.A. | N.A. | 15 | 48 | 15 | 37 | 26 | 15 |

Ring 1	1	2	3	4	9	10	11	12
Traffic Std ID	NO BARRIERS							
Ring 2	5	6	7	8	13	14	15	16

dia_si_2: Separate Intersection Phase Sequence

When a controller is initialized as a DIAMOND (MM->8->4), the default Phase Mode is DIAM and the Diamond Mode is 4Ø (Unit Parameters, MM->1->2->1). This Diamond Mode unit parameter may be changed to SEP for Separate Intersection operation. When active, “Seq 99” and “Sep” are displayed in the right hand corner of the Phase Timing Status screen. Sequence 99 cannot be edited and provides the following ring sequences:

Seq#	Ring	Sequence.of.Phases							
99	1	1	2	3	4	9	10	11	12
99	2	5	6	7	8	13	14	15	16
99	3	0	0	0	0	0	0	0	0
99	4	0	0	0	0	0	0	0	0

Default Sequence 99 - Separate Intersection Mode (Sep)

The phase concurrencies that apply when Separate Intersection Mode is active are as follows. Essentially, every phase may be concurrent with any phase in the other ring.

Phase	Ring	Concurrent Phase(s)	Phase Enabled
1	1	5-6-7-8-13-14-15-16	X
2	1	5-6-7-8-13-14-15-16	X
3	1	5-6-7-8-13-14-15-16	X
4	1	5-6-7-8-13-14-15-16	X
5	2	1-2-3-4-9-10-11-12	X
6	2	1-2-3-4-9-10-11-12	X
7	2	1-2-3-4-9-10-11-12	X
8	2	1-2-3-4-9-10-11-12	X
9	1	5-6-7-8-13-14-15-16	.
10	1	5-6-7-8-13-14-15-16	.
11	1	5-6-7-8-13-14-15-16	.
12	1	5-6-7-8-13-14-15-16	.
13	2	1-2-3-4-9-10-11-12	.
14	2	1-2-3-4-9-10-11-12	.
15	2	1-2-3-4-9-10-11-12	.
16	2	1-2-3-4-9-10-11-12	.

Figure dia_si_1: Phase, Ring and Concurrency Programming (Separate Intersection)

Default Programming Applied to Separate Ring Operation

- 1) Phases 9, 10, 11, 12, 13, 14, 15, 16 are omitted by the software and dual entry is not placed on any phase.
- 2) The Separate Intersection diamond mode automatically programs the Call and Extend detector parameters as

Det #	Call (default)	Switch	Extend (default)	Options
1	0	0	0.0	Call & Ext
2	2	0	0.0	Call & Ext
3	3	11	0.0	Call & Ext
4	4	12	0.0	Call & Ext
5	0	0	0.0	Call & Ext
6	6	0	0.0	Call & Ext
7	7	15	0.0	Call & Ext
8	8	16	0.0	Call & Ext
9	0	0	0.0	Call & Ext
10	0	0	0.0	Call & Ext
11	2	0	0.2	Call & Ext
12	4	12	0.2	Call & Ext
13	0	0	0.0	Call & Ext
14	0	0	0.0	Call & Ext
15	6	0	0.2	Call & Ext
16	8	16	0.2	Call & Ext
17	3	11	0.2	Call & Ext
18	7	15	0.2	Call & Ext

Default Detector Programming for Separate Intersection Operation

5 Diamond Coordination

Diamond Coordination is provided using the Easy coordination mode with or without floating force-offs. The Easy mode of coordination is discussed in the NTCIP Advanced Coordination manual. Each diamond mode implements the phase skipping features called for in the Texas Diamond Controller Specification.

5.1 Four Phase Diamond Coordination

The following guidelines must be applied when coordinating a 4-phase diamond controller:

- 1) The sum of the splits for the phases 2, 3, 4, 6, 7, 8 is equal to the cycle length. Omitted phases are assigned a zero split time.
- 2) The split times for phase 15 or 16 must be less than the split time for phase 2 and the split time for phase 11 or 12 must be less than the split time for phase 6. The split value for phase 2 split time must be large enough to contain the fixed intervals of phase 2 as well as the fixed intervals of either phases 15 or 16. The split value of phase 6 split time must be large enough to contain the fixed intervals of phase 6 as well as the fixed intervals of either phases 11 or 12. The split time of phase 9, left to right clearance, is less than the split time of either 2, or 3, or 4. The split time of phase 13, right to left clearance, is less than the split time of either 6, or 7, or 8. The split time of all clearance phases, 9, 11, 12, 13, 15, 16 will operate in a floating max mode, i.e. the maximum time calculated and used for each one of these phases is the Split time minus the yellow plus red clearance of each of the respective phases. The split time for phase 5 should be equal to at least the minimum split time of phases 2, 3 or 4. The split time for phase 1 should be equal to at least the minimum split time of phases 6, 7, or 8.
- 3) Individual split times must satisfy the minimum phase times programmed for each phase accounting for any short-way transition allowed for the pattern. The minimum vehicle phase time is the sum of the minimum green plus the yellow and all-red clearance times. If added initial is enabled for the phase detector, the larger of min green or max initial volume should be used. The minimum pedestrian phase time is the sum of the walk and pedestrian clearance times plus the yellow vehicle clearance (unless PedClr-Through-Yellow is enabled).
- 4) When selecting the coordinated phases for 4 phases operation, the selection of phase 2, 3, 4, 6, 7, or 8 is allowed. The operator must also place the coordinated phase on recall so that the controller will have a constant call on the coordinated phase when operating. The selection of the split time, recall, and coordinated phase follows the NTCIP split table object entry, TS 3.5 paragraph 2.5.9.
- 5) The controller will verify all of the above information before setting the coordination active. If the any of the above criteria fails, the controller will display one of the NTCIP reasons on the “coordination status screen” for the plan failure. These reasons can be found in the TS 3.5 paragraph 2.5.11.

5.2 Three Phase Diamond Coordination

Three Phase Coordination distributes the cycle between phase pairs 2 / 6, 4 / 8, and 3 / 7. The logic in the diamond is designed operates the controller in semi-actuated mode allowing individual phases to be skipped. The following rules apply to Three Phase Coordination:

1. The sum of the splits for phases 4, 9, 3, 2, 1 must equal the cycle length. The cycle length for ring 2 must equal to the sum of the splits of phases 8, 13, 7, 6, 5. Phases 10 and 14 are used and its splits must be set less than or equal to 4 and 8. The controller has internal logic to control these phases even though they are not part of the cycle length.
2. The barrier rule that applies is the sum of phases 1 and 2 splits must equal to the sum of phases 5 and 6. Also the sum of phases 3 and 9 splits must equal the sum of phases 7 and 13 splits.
3. Three Phase Coordination, like Four Phase Coordination must place the coordinated phase on recall.

5.3 Split Intersections Diamond Coordination

In the split intersections mode, any of the Ring 1 phases or any of the Ring 2 phases can be used for the coordinated phase. Since Ring 1 and Ring 2 are completely independent, the rings are not dependent upon each other for a timing relationship other than the cycle length being the same for each ring.

1. The sum of the splits of the phases for ring 1 (1+2+3+4) must equal the programmed cycle length. The sum of the splits of the phases for ring 2 (5+6+7+8) must also equal the programmed cycle length.