Standard for Double Diamond Overlap Phasing

Guidelines for Developing

Roads and Traffic Authority

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Revision history

Version	Date	Details
1.0	26 May 2009	Initial release
1.1	10 Nov 2009	Correction to Figure 3.

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1 Introduction

This document provides a description of double diamond overlap (DDO) phasing. It replaces the Standard for Double Diamond Overlap Design [3].

Single diamond overlap phasing is a method of controlling two opposing right turn movements at a signalised intersection by using overlap movements, alternative phasing and repeat right turns, Standard for Single Diamond Overlap Phasing [15]. This enables leading and trailing right turns to be used in the same cycle. Where it is necessary to signal control two sets of opposing right turn movements, the double diamond overlap (DDO) method, described herein, shall be adopted unless it can be proved that split approach or other phasing would be more efficient.

This method requires exclusive right turn lanes at the stop line, but it is efficient even where there is inadequate storage for right turn vehicles.

Reference is to be made on the design plan to this document. Any variations required are to be described on the design plan. Such variations should be confined to the control of left turning movements (e.g. where intersection geometry differs) or any pedestrian movements not required.

An enhancement to DDO operation is the filter option, where the right turn movements from the major and minor road may be permitted to filter during A or E phase, respectively, by sacrificing the right turn phase in the opposing direction (i.e. B or C phase).

The filter option may be provided for either or both of the right turn movements. This standard describes the differences in operation when the filter option is provided.

The general methods to be adopted in specifying the colour sequences for a Vehicle group, detector logic and pedestrian movements can be found in the specifications for Vehicle Group, Detector Logic and Pedestrian Movement operation [10], [11] and [12] respectively.

1.1 Definitions and abbreviations

Term	Meaning
DO	Diamond Overlap
LTRA	Left Turn Red Arrow
'major road'	is the road containing the two opposing right turn movements which need to be controlled. This is usually, but not necessarily, the road with the higher traffic flows.
'minor road'	is the road serviced by the side-street phases
PB	Push-button
RTA	Roads and Traffic Authority
DDO	Double Diamond Overlap
TMB	Traffic Management Branch

All other terms are defined in Traffic Signal Terminology [9].

1.2 References

[1] VD018-10, Standard for Detector Specification Schedule, 23 December 1988 (*also titled Standard Tables for Detector Logic, RTA Standard Personality, 24 November 1988*)

[2] VD018-5, Standard for Single Diamond Overlap Design

[3] VD018-6, Standard for Double Diamond Overlap Design

[4] VD018-8, Standard for Signal Group Displays

[5] VD018-14, Standard for Single Diamond Overlap Phasing with Filter Option

[6] TS-QA-156, Personality Standard Tables Management – Standard Operating Procedure

[7] Traffic Signals Practice, Design – RTA, October 1999

[8] RTA-TC-106, Traffic Signal Operation, Version 1.1, October 2000

[9] RTA-TC-118, Traffic Signal Terminology, Version 1.1, November 2000

1.3 Associated Documents

[10] TS-TN-019, Specification of Vehicle Group Operation – Guidelines for Developing

[11] TS-TN-020, Specification of Detector Logic Operation – Guidelines for Developing

[12] TS-TN-021, Specification of Pedestrian Movement Operation – Guidelines for Developing

[13] TS-TN-022, Specification of Ancillary Operation – Guidelines for Developing

[14] TS-TN-023, Layout of Macros for Standard Tables – Guidelines

[15] TS-TN-026, Standard for Single Diamond Overlap Phasing

[16] RTA_TC-185, RTA Standard Personality Reference Manual (Phases)

2 Format and Explanation

The double diamond overlap designs have two diamond phases. To distinguish between the two in the standard table description the terms 'complimentary' and 'other' have been used,

- 'Complimentary' is used to refer to the diamond phase which has the left turn movement in the diamond phase and one of the alternative phases. For example, the left turn movement marked with an asterisk * in Figure 1 below.
- 'Other' is used to refer to the diamond phase which has the left turn movement in only one of the alternative phases. For example, the left turn movement marked with an asterisk * in Figure 2 below.

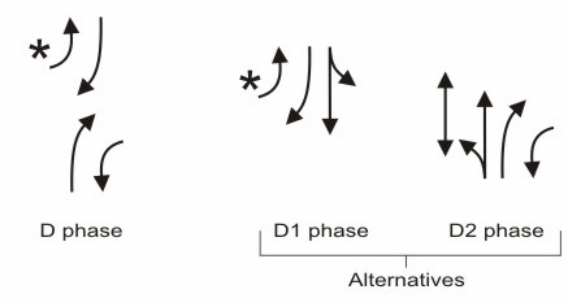


Figure 1 Complimentary diamond phase

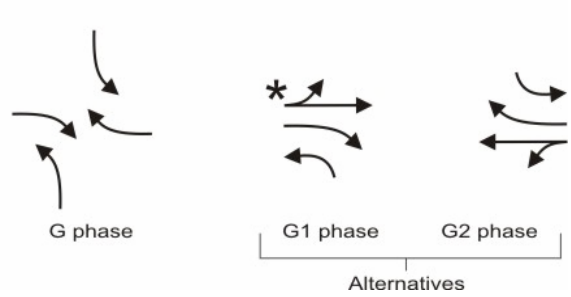


Figure 2 Other diamond phase

3 Double Diamond Overlap – Non Filter

The following sections describe in detail the operation of a non filter double diamond overlap intersection. Figure 3 illustrates a typical layout and phasing for a double diamond overlap.

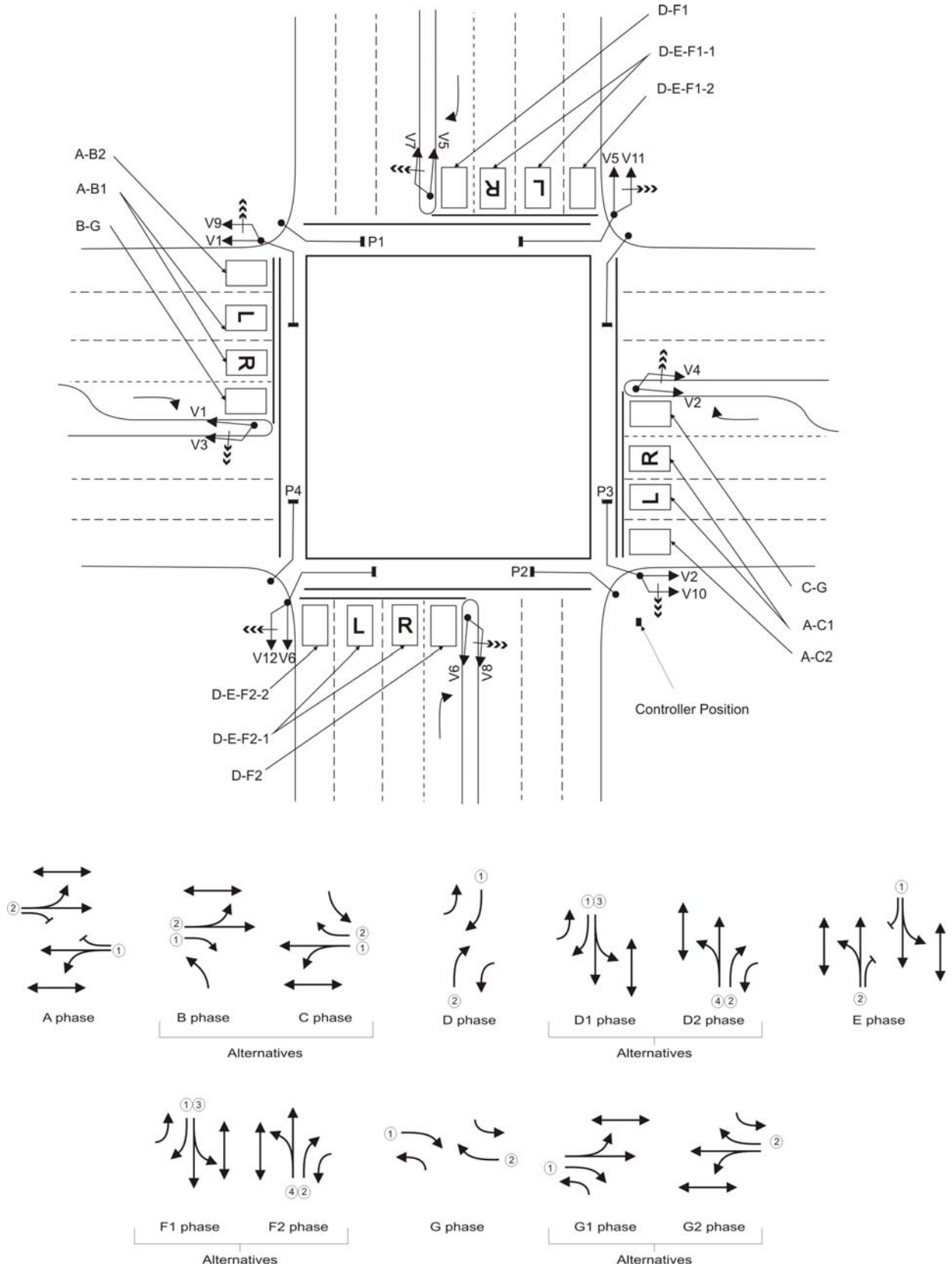


Figure 3 Typical Intersection Layout and phasing for Double Diamond Overlap

3.1 G Phase

G phase is considered to be the first phase. It is introduced as a result of demands on both B-G and C-G right turn detectors.

When there is a demand on only one detector, the diamond movement is skipped and the appropriate G1 or G2 overlap is introduced.

If, during G phase, a gap or waste expiry occurs on the opposite (turning) detector, the controller will immediately change to the appropriate alternative overlap (G1 or G2). This change occurs without resetting the timers (gap, waste/headway, maximum). The duration of the overlap phase (G1 or G2) is subject to the expiry of these timers.

If during G phase there is no gap or waste expiry on either detector, G phase will be terminated by the maximum time and the controller will move to A phase.

3.2 A Phase

The A phase must always follow G (G1 or G2) phase. As an option, A phase may be introduced automatically each cycle. If during A phase there is a further demand on either or both right turn detectors (B-G and/or C-G), one of the alternative repeat overlaps (B or C phase) will be introduced subject to the following conditions in:

- Isolated Operation

  (a) The previous cycle length exceeded X seconds, as set in the controller special timesetting 9 (S9 SCATS, B.9 keyboard), and

  (b) A gap or waste expiry occurs on the opposing through detector (A-C or A-B) during A phase. In the event of simultaneous expiry of approaches for both through detectors, the controller will move to B phase.

- Flexilink & Masterlink Operation

  For Masterlink and Flexilink operation, the presence of the Z- signal allows an actuation on the B-G1 detector to place a demand for B unconditionally. Similarly, the presence of the Z+ signal allows an actuation on the C-G2 detector to unconditionally place a demand for C phase.

If B phase or C phase is introduced, it may be extended (unless there is an expiry of both gap (or waste) timers for the through and right turn detectors) for the unused time of A phase, plus the allotted B or C time (unused maximum time transfer).

The A phase shall be enabled to steal maximum time from B and/or C phases. That is, upon expiry of the A phase maximum time, the maximum timer may be restarted using B phase (or C phase) maximum time, provided no demand was present for B phase (or C phase). The phase(s) losing the maximum time are then inhibited from being introduced in the current cycle, except when:

a) A phase expires with at least 15 seconds of maximum time remaining; and

b) a demand is present for B phase (or C phase).

If B phase (or C phase) is introduced in this manner then the maximum times is limited to the unused maximum time remaining from A phase.

3.3 D Phase

D phase is introduced as a result of demands on both D-F1 and D-F2 detectors. When there is a demand on only one detector, the diamond movement is skipped and the appropriate D1 or D2 overlap phase is introduced.

If during D phase a gap or waste expiry occurs on the opposite (turning) detector and there is a demand for E phase, the controller will immediately change to the appropriate alternative overlap (D1 or D2). This change occurs without resetting the timers (gap, waste/headway, maximum). The duration of the overlap phase (D1 or D2) is subject to the expiry of these timers.

If during D phase there is no gap or waste expiry on either detector, D phase will be terminated by the maximum time and the controller will move to the next demanded phase in sequence.

3.4 E Phase

E phase follows D (D1 or D2). If during E phase there is a further demand on either or both right turn detectors (D-F1 and/or D-F2), one of the alternative repeat overlaps (F1 or F2) will be introduced subject to the following conditions, in:

- Isolated Operation

  (a) The previous cycle length exceeded Y seconds, as set in the controller special timesetting 10 (S10 SCATS, B.10 keyboard); and

  (b) A gap or waste expiry occurs on the opposing through detector (D-E-F1 or D-E-F2) during E phase. In the event of simultaneous expiry of the approaches for both through detectors, the controller will move to F1 phase.

- Masterlink and Flexilink

  For Masterlink and Flexilink operation, setting bit 4 in the SCATS extra special facilities allows an actuation on the D-F1 detector to place a demand for F1 unconditionally. Similarly, setting bit 5 allows an actuation on the D-F2 detector to unconditionally place a demand for F2 phase. Note: bit 4 and bit 5 refer to the XSF (Extra Special Facilities) 5 and 6, respectively, message from SCATS.

E phase shall be enabled to steal maximum time from F phase. That is, upon expiry of the E phase maximum time, the maximum timer may be restarted using the F phase maximum time, provided no demand was present for F1 or F2 phase. If the maximum is stolen from F phase, then F1 and F2 phases are inhibited from being introduced in the current cycle, except when:

a) E phase expires with at least 15 seconds of maximum time remaining; and

b) a demand is present for F1 or F2 phase.

If F1 or F2 phase is introduced in this manner then the maximum time is limited to the unused maximum time remaining from E phase.

3.5 Pedestrian Facilities

All pedestrian signal groups (P1, P2, P3 and P4) are independent.

3.5.1 P1

The push-buttons associated with the P1 signal group demand A phase (P1). The walk is introduced concurrently with the V1 green. If the walk is introduced at the start of A, B or G1 phase, the walk interval starts timing at the start of the phase. The walk and clearance intervals can then overlap into B or A phase. However, they are not permitted to overlap into G1 because the controller will not decide whether or not G1 will run until after the extension green interval going to G phase.

3.5.2 P2

The push-buttons associated with the P2 signal group demand A phase (P2). The walk is introduced concurrently with the V2 green. If the walk is introduced at the start of A, C or G2 phase, the walk interval starts timing at the start of the phase. The walk and clearance intervals can then overlap into C or A phase. However, they are not permitted to overlap into G2 because the controller will not decide whether or not G2 will run until after the extension green interval going to G phase.

3.5.3 P3

The push-buttons associated with the P3 signal group demand E phase. If D1 phase is introduced, the P3 walk is introduced concurrently with the V5 green and can overlap into E phase. The minimum walk time commences timing from the introduction of the walk display with V5 green.

3.5.4 P4

The push-buttons associated with the P4 signal group demand E phase. If D2 phase is introduced, the P4 walk is introduced concurrently with the V6 green and can overlap into E phase. The minimum walk time commences timing from the introduction of the walk display with the V6 green.

3.6 Detectors

The following detector specification schedule applies to this standard but is not required to be repeated on the design plan. However, any variations must be shown either in an abridged table or in note form.

DETECTOR	SPECIFICATION				
A-B* [A-B1] ※ [A-B2]	FN	A(L)	A(E2)	B(E2)	
	SG/PS	$\overline{V1}$	A	B	
	DS	----	$\overline{B(NEXT)}$	$\overline{A(NEXT)}$	
A-C* [A-C1] ※ [A-C2]	FN	A(L)	A(E1)	C(E1)	
	SG/PS	$\overline{V2}$	A	C	
	DS	----	$\overline{C(NEXT)}$	$\overline{A(NEXT)}$	
B-G	FN	V3(CL)	V3(E1)		
	SG/PS	$\overline{V3}$	V3		
	DS	SEE NOTES			
C-G	FN	V4(CL)	V4(E2)		
	SG/PS	$\overline{V4}$	V4		
	DS	SEE NOTES			
D-F1	FN	V7(CL)	V7(E1)		
	SG/PS	$\overline{V7}$	V7		
	DS	SEE NOTES			
D-F2	FN	V8(CL)	V8(E2)		
	SG/PS	$\overline{V8}$	V8		
	DS	SEE NOTES			
D-E-F1 [D-E-F1-1]※ [D-E-F1-2]	FN	E(L)	D1(E3)	E(E1)	F1(E3)
	SG/PS	$\overline{V5}$	D1	E	F1
	DS	----	$\overline{E(NEXT)}$	$\overline{D1(NEXT)}.\overline{F1(NEXT)}$	$\overline{E(NEXT)}$
D-E-F2 [D-E-F2-1]※ [D-E-F2-2]	FN	EL)	D2(E4)	E(E2)	F2(E4)
	SG/PS	$\overline{V6}$	D2	E	F2
	DS	----	$\overline{E(NEXT)}$	$\overline{D2(NEXT)}.\overline{F2(NEXT)}$	$\overline{E(NEXT)}$

DETECTOR	SPECIFICATION		
P1	FN	A(PB)	E(L)
	SG/PS	$\overline{P1(WALK)}$	$\overline{V1.P1(WALK)}$
	DS	SEE NOTES	$\overline{C}.\overline{D}.\overline{D1}.\overline{D2}.\overline{E}.\overline{F1}.\overline{F2}.\overline{G}.\overline{G2}$
P2	FN	A(PB)	E(L)
	SG/PS	$\overline{P2(WALK)}$	$\overline{V2.P2(WALK)}$
	DS	SEE NOTES	$\overline{B}.\overline{D}.\overline{D1}.\overline{D2}.\overline{E}.\overline{F1}.\overline{F2}.\overline{G}.\overline{G1}$
P3	FN	E(PB)	A(L)
	SG/PS	$\overline{P3(WALK)}$	$\overline{V5.P3(WALK)}$
	DS	SEE NOTES	$\overline{A}.\overline{B}.\overline{C}.\overline{D}.\overline{D2}.\overline{F2}.\overline{G}.\overline{G1}.\overline{G2}$
P4	FN	E(PB)	A(L)
	SG/PS	$\overline{P4(WALK)}$	$\overline{V6.P4(WALK)}$
	DS	SEE NOTES	$\overline{A}.\overline{B}.\overline{C}.\overline{D}.\overline{D1}.\overline{F1}.\overline{G}.\overline{G1}.\overline{G2}$

* The A phase must always follow G (G1 or G2) phase. As an option, A phase may be introduced automatically each cycle.

※ Where left turn arrow lanterns are provided, the detectors are labelled as indicated in square brackets and the demand function of the detector in the kerbside lane is made subject to a presence timer.

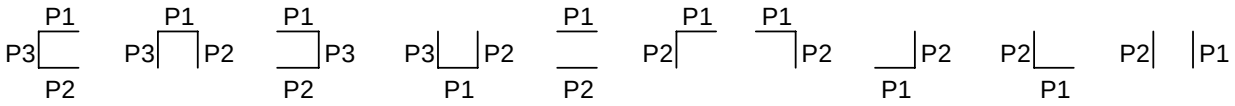
This table must be read in conjunction with the notes. Any variation from this standard is to be shown on the plan.

Figure 4 Standard Detector Specification Schedule for Double Diamond Overlap

Notes

1. When A phase has been allocated, the numbering of signal groups is arranged to suit the positioning of the controller on either of the corners indicated in Figure 3.

2. Where one or more pedestrian crossings are omitted, the remainder are to be numbered as follows (assuming B phase Figure 3 – orientated thus ⟶)



3. Left turn arrow signal groups are always numbered last and in the following order (see Figure 3):

   a) Approach adjacent to V1 movement – (V9)

   b) Approach diagonally opposite (a) – (V10)

   c) First left turn movement in side street (clockwise from V1 movement) – (V11)

   d) Approach diagonally opposite (c) – (V12)

   Where any such left turn movement is un-signalised, the signal group number passes to the next signal group in the above order.

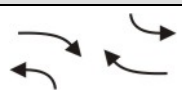
SG	Phase During Which Green Displayed											Overlaps Permitted	Overlap Conditions	Duration of LTRA
	A	B	C	D	D1	D2	E	F1	F2	G	G1	G2			
V1	X	X									X		G1/A/B, B/A, A/G1*	*P1 not running	
V2	X		X									X	G2/A/C, C/A, A/G2*	*P2 not running	
V3		X								X	X		G/G1, B/G		
V4			X							X		X	G/G2, C/G		
V5					X		X	X					D1/E/F1		
V6						X	X		X				D2/E/F2		
V7				X	X			X					D/D1		
V8				X		X			X				D/D2		
V9				X	X			X					D/D1, F1/G1*, F1/A*	*P1 not demanded	Arrow time
V10				X		X			X				D/D2, F2/G2*, F2/A*	*P2 not demanded	Arrow time
V11			X							X		X	C/D1*, C/E*, G/G2	*P3 not demanded	Arrow time
V12		X								X	X		B/D2*, B/E*, G/G1	*P4 not demanded	Arrow time
P1	X	X									X		G1/A/B	See section 3.5.1	
P2	X		X									X	G2/A/C	See section 3.5.2	
P3					X		X	X					D1/E	See section 3.5.3	
P4						X	X		X				D2/E	See section 3.5.4	

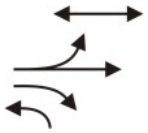
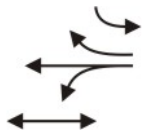
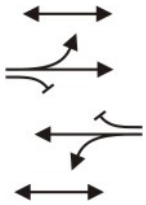
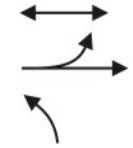
Notes

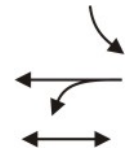
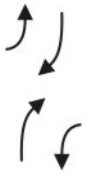
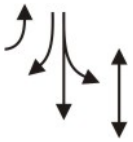
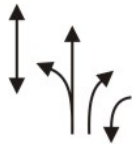
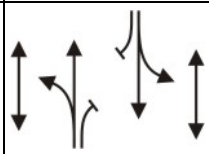
1. The above chart should be shown on the design plan as a key to the display of signal groups.
2. Where an overlap condition only applies to a particular permitted overlap sequence, the phase sequence and condition are both identified with an asterisk *.

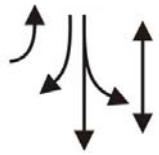
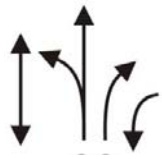
Figure 5 Standard Signal Group/Phase Chart for Double Diamond Overlap

3.7 Summary of Double Diamond Overlap

Phase	Movements	Detector	Demand Conditions	Extensions
G		B-G and C-G	Demand on both detectors. Demand(s) cancelled if either detector vacated during B or C.	Only extended while no gap or waste expiry on either detector

Phase	Movements	Detector	Demand Conditions	Extensions
G1		B-G	a) Following G phase as a result of a gap or waste expiry on C-G detector OR b) If G phase skipped (no C-G demand). Demand cancelled if detector vacated during B phase.	Timers (gap, waste, maximum) are not reset when changing from G to G1.
		P1 PB's	PB demand alone will not introduce G1 phase, but if G1 is introduced as in a) or b) above, the P1 walk is introduced concurrently with V1 green. The termination of G1 shall not be inhibited by the P1 walk. The walk or clearance may overlap into A or B phase.	
G2		C-G	a) Following G phase as a result of a gap or waste expiry on B-G detector OR b) If G phase skipped (no B-G demand). Demand cancelled if detector vacated during C phase.	Timers (gap, waste, maximum) are not reset when changing from G to G2.
		P2 PB's	PB demand alone will not introduce G2 phase but if G2 is introduced as in a) or b) above, the P2 walk is introduced concurrently with V2 green. The termination of G2 shall not be inhibited by the P2 walk. The walk or clearance may overlap into A or C phase.	
A		A-B [A-B1] ※ [A-B2]	The A phase must always follow G (G1 or G2) phase. As an option, A phase may be introduced automatically each cycle. No demand is placed while V1 is displaying green or yellow.	Approach 2 extended unless changing to B phase.
		A-C [A-C1] ※ [A-C2]	A phase must always follow G (G1 or G2) phase. As an option, A phase may be introduced automatically each cycle. No demand is placed while V2 is displaying green or yellow.	Approach 1 extended unless changing to C phase.
		P1 PB's	Normally calls A phase but walk introduced with V1 green as described in G1 phase. Calls received when V1 signal group is green are stored until next cycle.	
		P2 PB's	Normally calls A phase but walk introduced with V2 green as described in G2 phase. Calls received when V2 signal group is green are stored until next cycle.	
B		B-G	Demand received prior to termination of A phase. This demand is satisfied subject to the conditions as set out in section 3.2.	Extends B phase normally.
		A-B		Extends B phase unless A phase is next.

Phase	Movements	Detector	Demand Conditions	Extensions
C		C-G	Demand received during A phase. This demand is satisfied subject to the conditions as set out in section 3.2.	Extends C phase normally.
		A-C		Extends C phase unless A phase is next.
D		D-F1 and D-F2	Demand on both detectors. Demand(s) cancelled if either detector vacated during F1 or F2.	Only extended while no gap or waste timer expiry on either detector.
D1		D-F1	a) Following D phase as a result of a gap or waste expiry on D-F2 detector OR b) If D phase skipped (no D-F2 demand). Demand cancelled if detector vacated during F1 phase.	Timers (gap, waste maximum) are not reset when changing from D to D1.
		P3 PB's	PB demand alone will not introduce D1 phase, but if D1 is introduced as in a) or b) above, the P3 walk is introduced concurrently with V5 green. The termination of D1 shall not be inhibited by the P3 walk or clearance which may overlap to E phase. No overlap is permitted from E to F1.	
D2		D-F2	a) Following D phase as a result of a gap or waste expiry on D-F1 detector OR b) If D phase skipped (no D-F1 demand). Demand cancelled if detector vacated during F2 phase.	Timers (gap, waste, maximum) are not reset when changing from D to D2.
		P4 PB's	PB demand alone will not introduce D2 phase, but if D2 is introduced as in a) or b) above, the P4 walk is introduced concurrently with V6 green. The termination of D2 shall not be inhibited by the P4 walk or clearance which may overlap to E phase. No overlap is permitted from E to F2.	
E		D-E-F1 [D-E-F1-1] [D-E-F1-※]	No demand is placed while V5 is displaying green or yellow.	Approach 1 extended unless changing to F1 phase.
		D-E-F2 [D-E-F2-2] [D-E-F2-※]	No demand is placed while V6 is displaying green or yellow.	Approach 2 extended unless changing to F2 phase.
		P3 PB's	Normally calls E phase but walk introduced with V5 green as described in D1 phase. Calls received when V5 signal group is green are stored until next cycle.	

Phase	Movements	Detector	Demand Conditions	Extensions
		P4 PB's	Normally calls E phase but walk introduced with V6 green as described in D2 phase. Calls received when V6 signal group is green are stored until next cycle.	
F1		D-F1	Demand received prior to termination of E phase. This demand is satisfied subject to the conditions in section 3.4.	Extends F1 phase normally.
		D-E-F1		Extends F1 phase.
F2		D-F2	Demand received prior to termination of E phase. This demand is satisfied subject to the conditions in section 3.4.	Extends F2 phase normally.
		D-E-F2		Extends F2 phase.

※ Where left turn arrow lanterns are provided, the detectors are labelled as indicated in square brackets and the demand function of the detector in the kerbside lane is made subject to a presence timer (PR).

4 Application of Filter Option

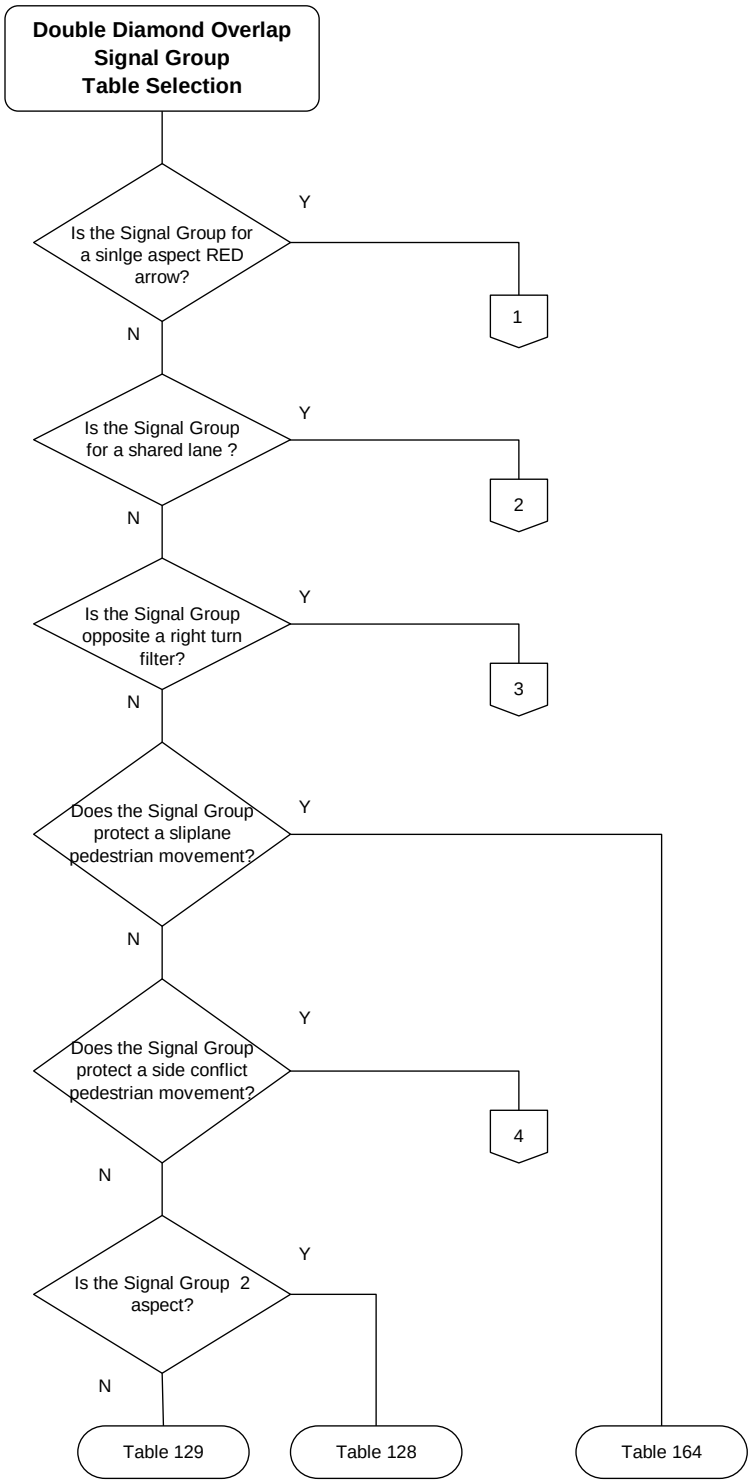
Double diamond overlap phasing with filter option may be used if the conditions for a double diamond overlap are satisfied (see section 2) and it is safe for either or both of the opposing right turns from the major road to filter and it is safe for either or both of the opposing right turns from the minor road to filter.

Each of the right turns from the major and minor road should be tested separately to determine whether filtering can be permitted. The tests are briefly described in Traffic Signal Practice: Design [7]. If neither of the right turns can be permitted to filter, then the site should operate as a double diamond overlap.

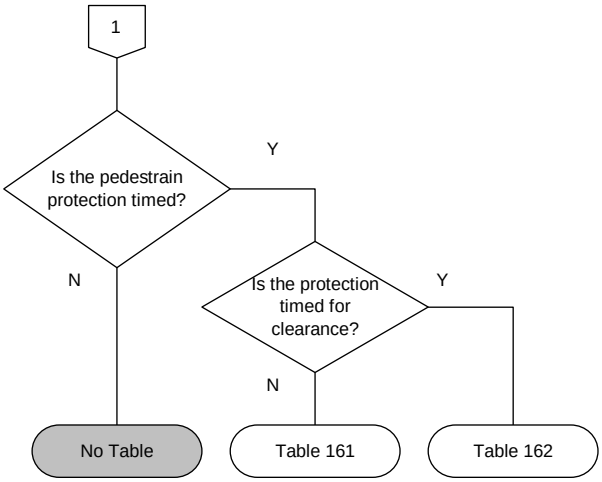
If either of the right turns can be permitted to filter, further analysis should be carried out to determine whether the filter will provide sufficient capacity to clear the right turning vehicles (see ARRB Research Report *ARR 123 Traffic Signals: Capacity and Timing Analysis*) and what times of the day and days of the week that filtering is to be permitted. Factors to consider include traffic flows, the probability of conflicts with pedestrians (particularly school children, elderly or handicapped pedestrians), previous accident patterns and traffic management requirements. If the tests indicate that filtering can be permitted 24 hours per day and 7 days per week, then a double diamond overlap with filter option may not be appropriate and simpler phasing should be used instead.

5 Standard Table Selection Charts

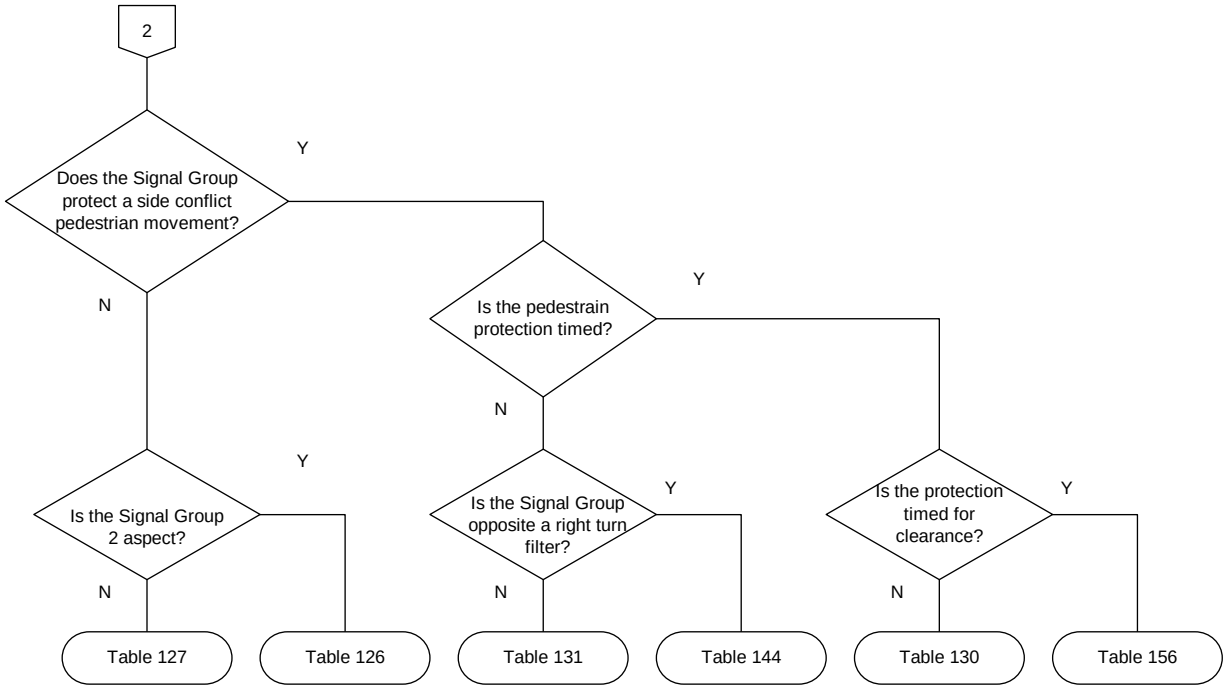
5.1 Selection Chart – Sheet 0



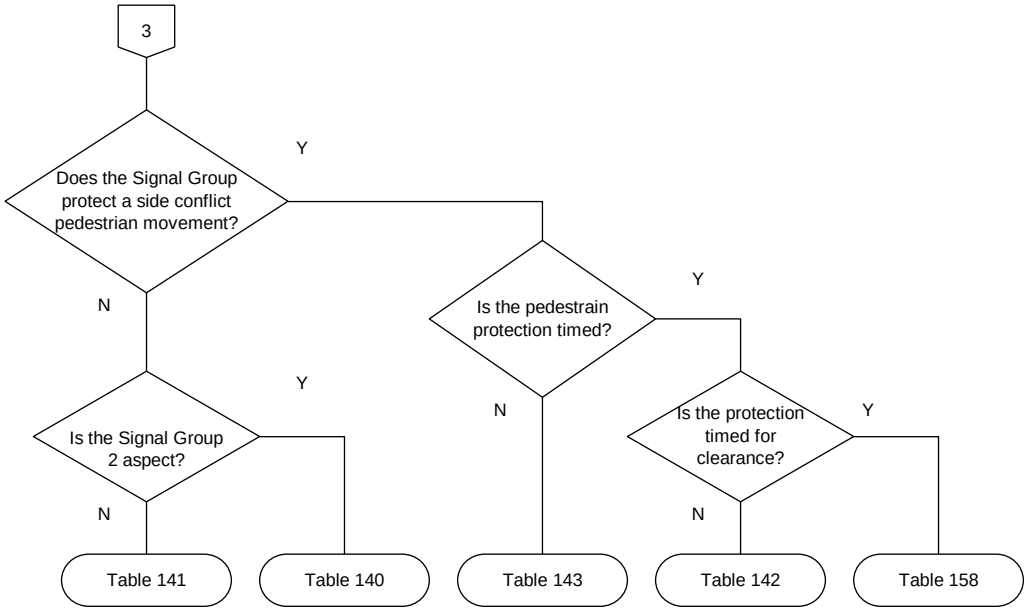
5.2 Selection Chart – Sheet 1



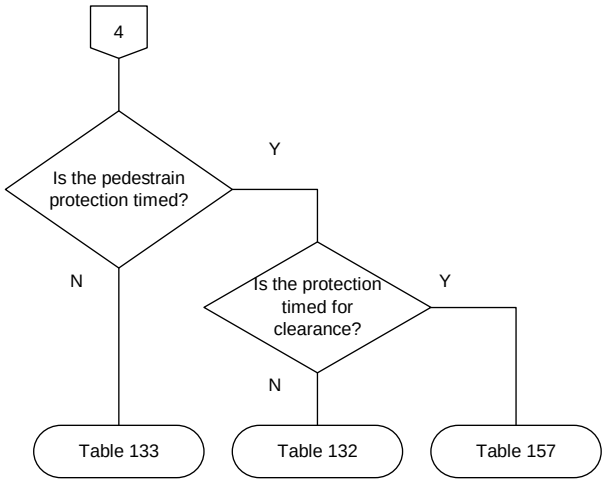
5.3 Selection Chart – Sheet 2



5.4 Selection Chart – Sheet 3



5.5 Selection Chart – Sheet 4



6 Standard Table Selection Guides

6.1 Single Aspect

Pedestrian protection timed during walk	Table 161
Pedestrian protection timed during clearance	Table 162
Pedestrian protection for walk & clearance	*Table 163*

6.2 Two Aspect

No pedestrian conflict.

Shared lane	Table 126
Exclusive lane, no opposite right turn filter	Table 128
Exclusive lane, optional opposite right turn filter	Table 140

6.3 Standard Three Aspect

Slip lane pedestrian conflict.

Exclusive lane, no opposite right turn filter	Table 164

	No Pedestrian	Pedestrian Protection		
		timed during walk	timed during clearance	for walk & clearance
Shared left turn lane – no opposite right turn filter	127	130	156	131
shared left turn lane – optional opposite right turn filter	127	130	156	144
Exclusive left turn lane – no opposite right turn filter	129	132	157	133
Exclusive left turn lane – optional opposite right turn filter	141	142	158	143

6.4 Vehicle Group Tables

The single diamond overlap tables are described and given in Standard for Single Diamond Overlap Phasing [15].

The following diamond overlap tables below will work for 7 phase double diamond overlap designs.

- Tables 126 - 133 inclusive.
- Tables 140 - 144 inclusive (filter option only).
- Tables 156 - 158 inclusive.
- Tables 161 - 164 inclusive.

The diamond phase for the main road must be G phase. The diamond phase for the side road must be D phase.