Add Traffic Signal Head Phasing Diagram / Table to Reduce Connection Errors and to Improve Safety

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Abstract

Traffic signals are becoming more and more complicated nowadays. Traditionally, traffic engineers will design or modify the intersection based on demand analysis (proposed volume, traffic count data, field observation, accident history and warrant analysis). Then drafters will draw the Phasing / Construction / Traffic Signals diagrams for this intersection using CAD software. Technologists will then implement timing plans and program databases based on the drafts and equipment available. Then the drawings and timing plan, database will be handed into signal installers. During all this process, if one chain is broken, then traffic signal safety and operation can be in hazardous situation. The proper application and design of the traffic signal is a key component in improving the safety and efficiency of the intersection. To remove all the uncertainness, a Traffic Signal Head Phasing Diagram / Table will clarify unnecessary confusion.

While intersections are becoming more complicated, more functions/phases/movement are needed to adapt to different vehicle and pedestrian requirement, complicated phase sequences and signal head setup come along with it. A few examples are shown in this text, including Fully Protected Left-Turn, Protected-Permissive Left-Turn, Dallas Display and Flashing-Yellow-Arrow for Protected/Permissive Left-Turn, 4-phase Diamond Interchange. Traditional simple signal head design without clear designation may not work well for these complex situations. The solution is to draw a Traffic Signal Head Phasing Diagram/Table.

The diagram can be drawn in existing traffic signal diagram, just by adding a few notations on the side of signal heads explaining the phase number or overlap number for that signal head's Red, Yellow, Green Arrow and Green Ball. A signal head /phasing table can be drawn to more clearly explain which color in Signal head is driven by which phase or overlap. It sounds like a simple improvement, but for large intersections this process will simplify the guessing process by installers, make engineer's intention much clear, and also make the installers' job much easier by reducing the risk of wrong connections!

The signal head phasing diagram can avoid unnecessary guesses from traffic professionals, provide a much clearer image of the operation of the controllers and traffic signal indications. One image is worth more than a thousand words!

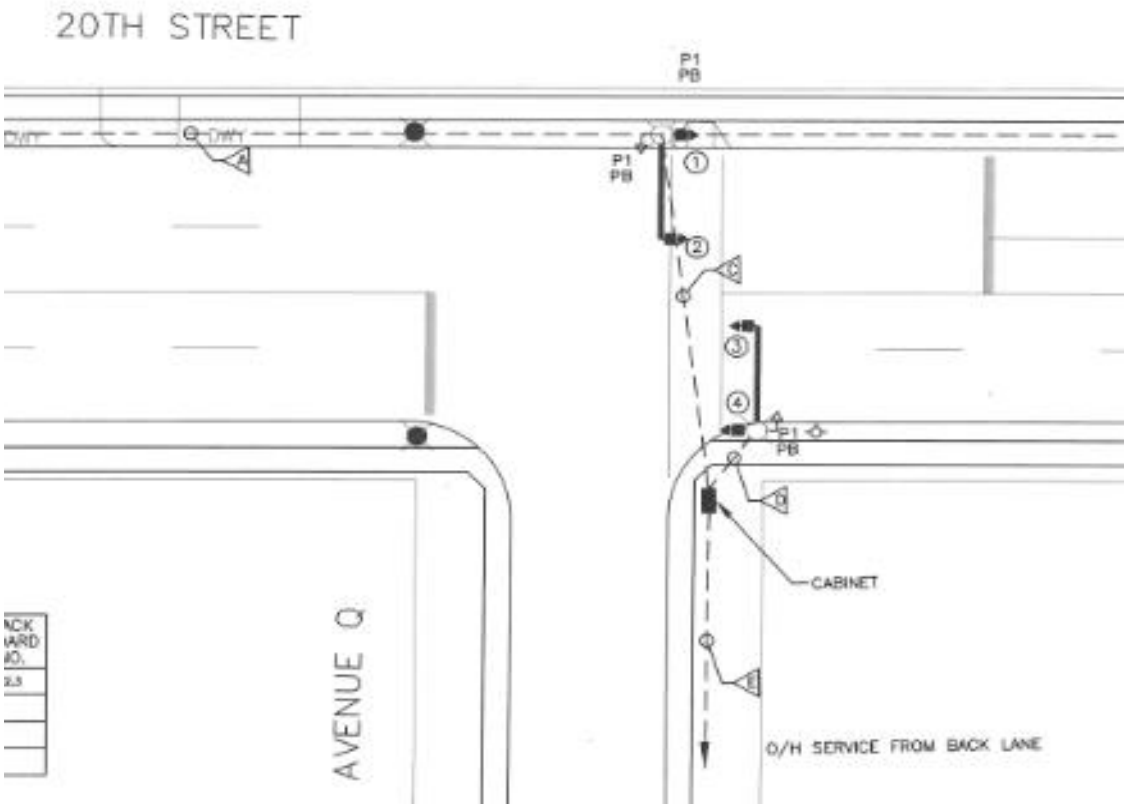
Content

1. Different traffic demands lead to different level of complexity for design and traffic control devices

Since traffic light's first implementation in Dec 1868, traffic signal has evolved from simple, manually operated gas-lit signal to electro-mechanical device, to full electronics in the past 150 years. Increased demands push the industry to develop more and more powerful machines to deal with more and more complicated situations. Here are a few examples to show the change.

1) Example1: Figure 1 shows a simple 2 phase controller/cabinet combination for a pedestrian-actuated signal

Fig1. 2-phase pedestrian-actuated signal



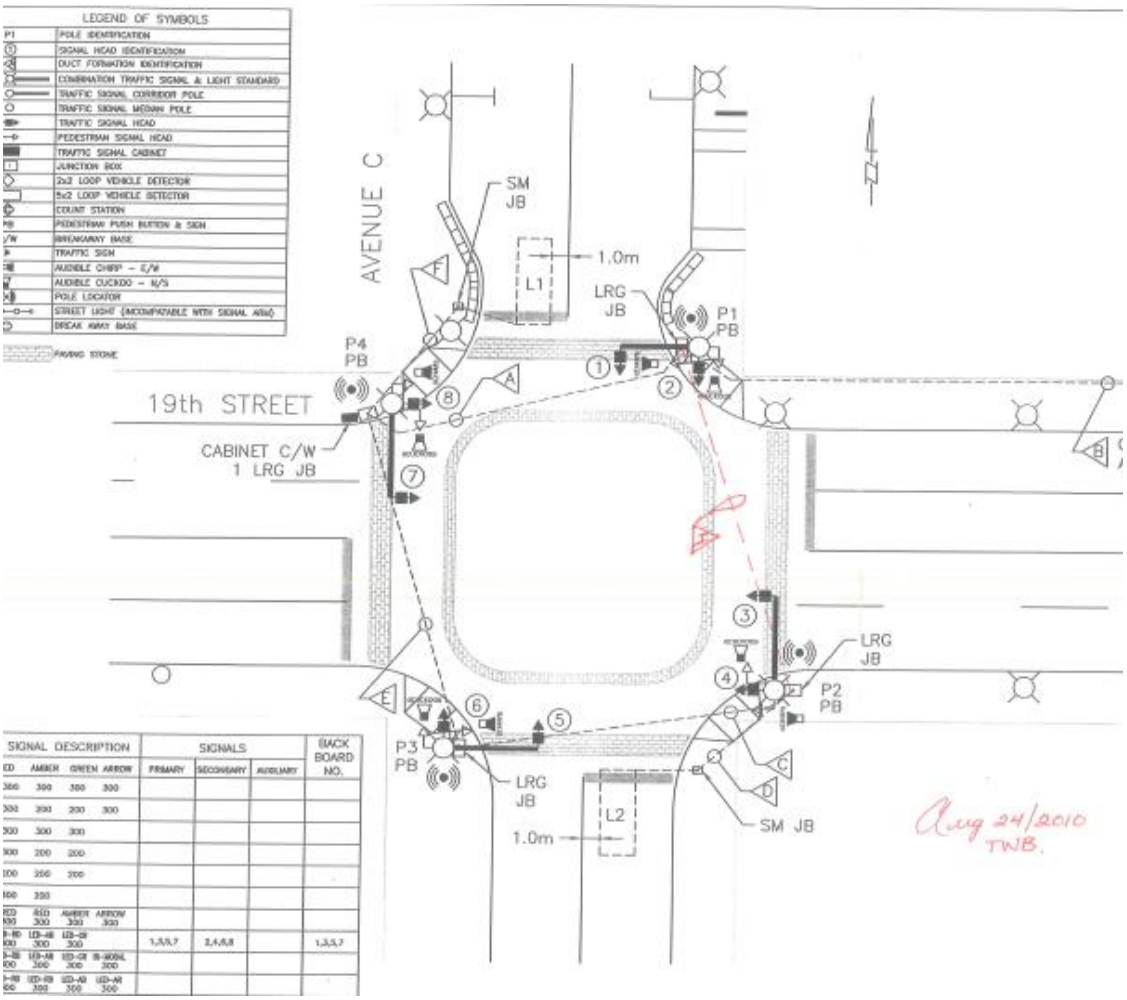
Phase Sequence

ph1 (NS ped)	ph2 (EW Vehicle)

No Problem, it is easily seen there!

2) Example 2: Figure 2 shows a 4-phase controller/cabinet combination for a semi-actuated intersection.

Fig 2. 4-phase semi-actuated signal



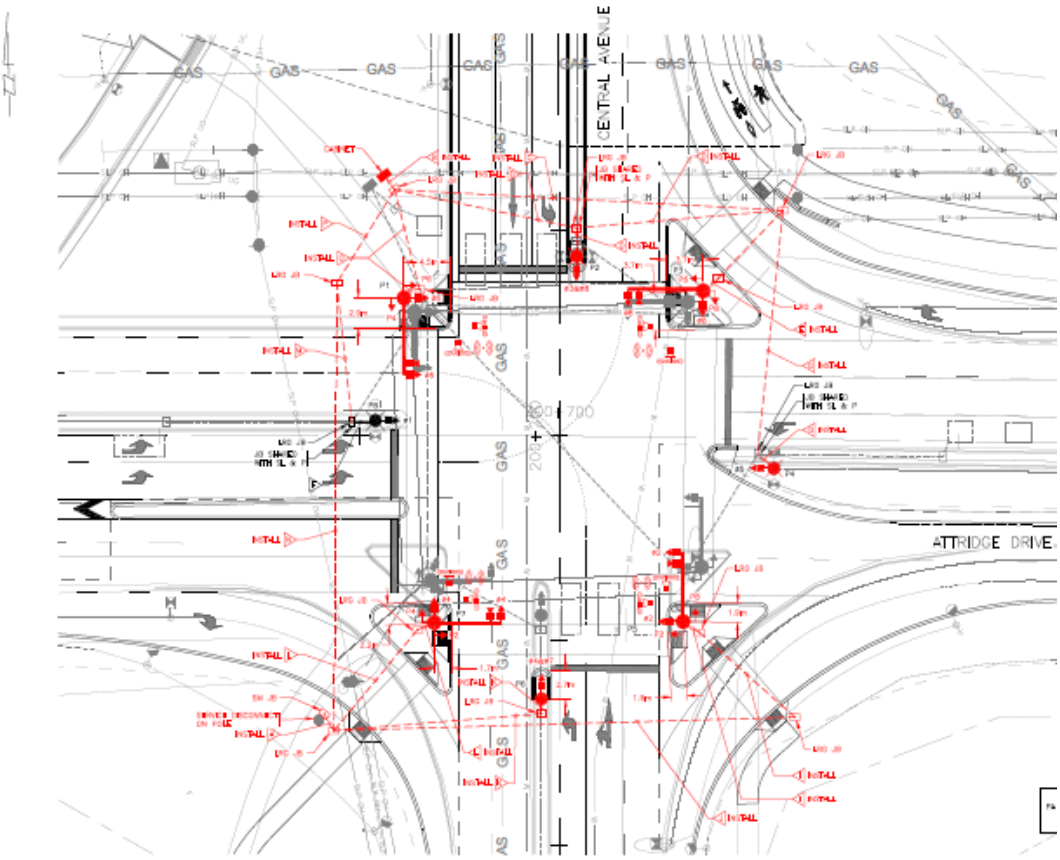
Phase Sequence

2	4
6	8

4 vehicle phases & 4 pedestrian phases

OK, we are professionals, we know how to wire those vehicle heads and pedestrian heads! ☺

3) Example 3: Figure 3 shows a 8-phase controller/cabinet combination

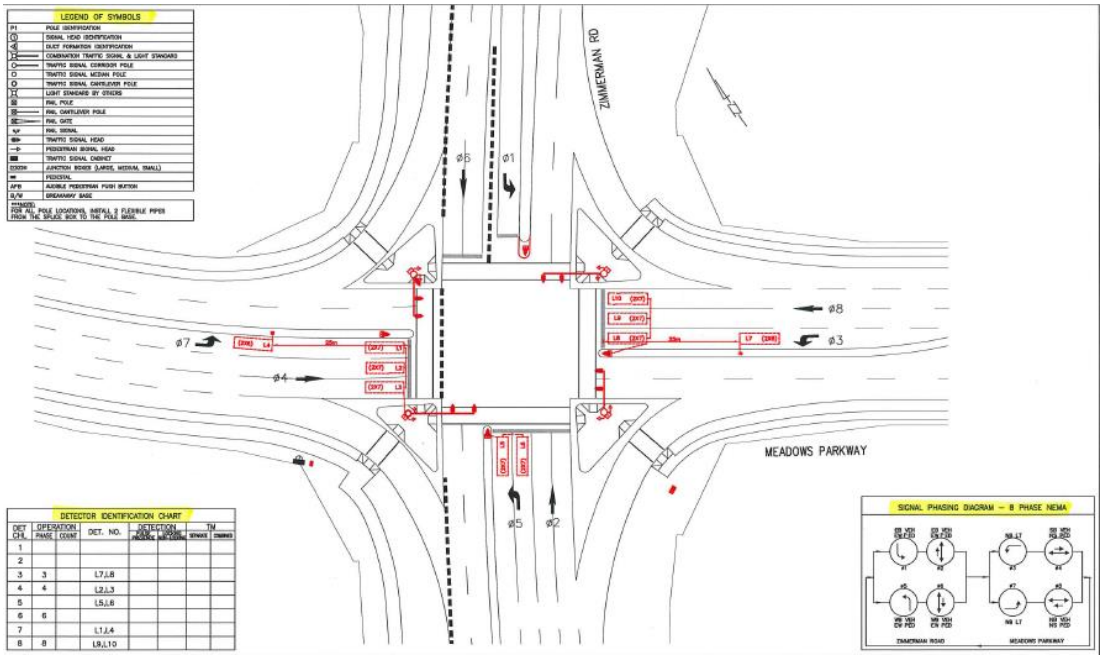


2,1	3	4
5,6	8	7

East-West: Lead-Lag
North-South: Split Phasing
All left turns are fully-protected

This drawing looks colorful, is not it? But more importantly, the complexity in design and implementation increases!

4) Example 4: Figure 4 shows a standard NEMA 8-phase intersection



Phase Sequence:

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

Left-turn phases 1,3,7 are protected-permissive. However due to the dual left turn movement for NBLT, ph5 is fully-protected.

5) Example 5: Figure 5 shows a 4-phase diamond interchange

**********Ref 4.2

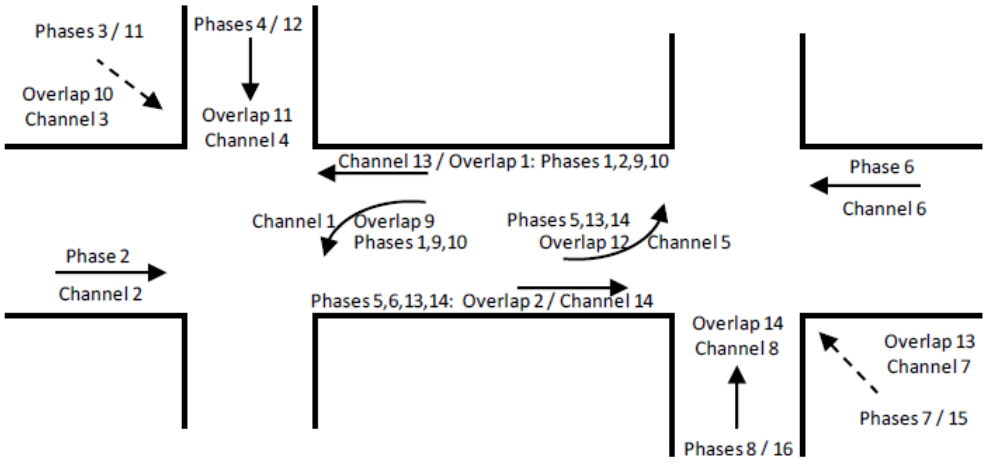
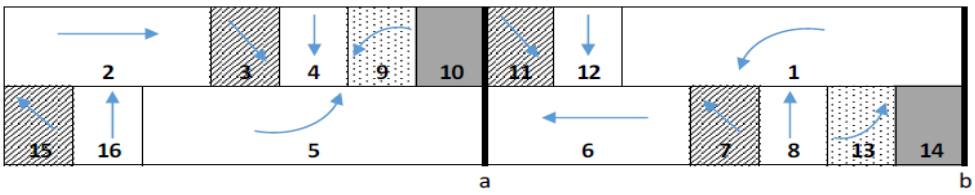


Fig 6. 4-phase Diamond Interchange phase sequence



What???

2. Clear up some confusions

Lots of traffic accidents come from left/right turns, lots of problems come from left/right turns as well. We often hear people talk about fully-protected left turn, protected-permissive left turns. What do they really mean?

I found the best explanation are from FHWA's website "Signalized Intersections: Information Guide"----FHWA Publication Number: FHWA-HRT-04-091 Date: August 2004 **********Ref 4.1

https://www.fhwa.dot.gov/publications/research/safety/04091/04091.pdf

1) Protected-Only Left-Turn phasing (Chapter 4.2.2)

"Protected-only" phasing consists of providing a separate phase for left-turning traffic and allowing left turns to be made only on a green left arrow signal

indication, with no pedestrian movement or vehicular traffic conflicting with the left turn. ……This phasing pattern is illustrated in figure 7.

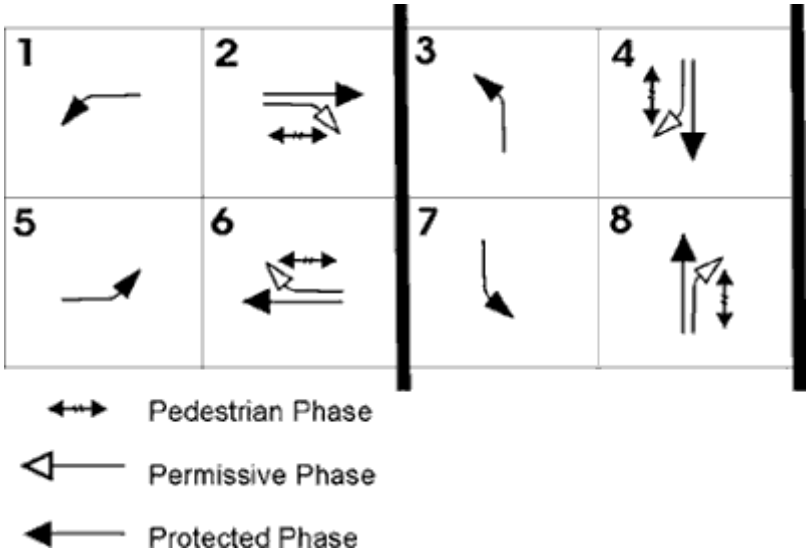


Figure 7. Typical phasing diagram for “protected-only” left-turn phasing

2) Protected-Permissive Left-Turn phasing – Chapter 4.2.3

A combination of protected and permissive left-turn phasing is referred to as protected-permissive left-turn (PPLT) operation. This phasing pattern is illustrated in Figure 8.

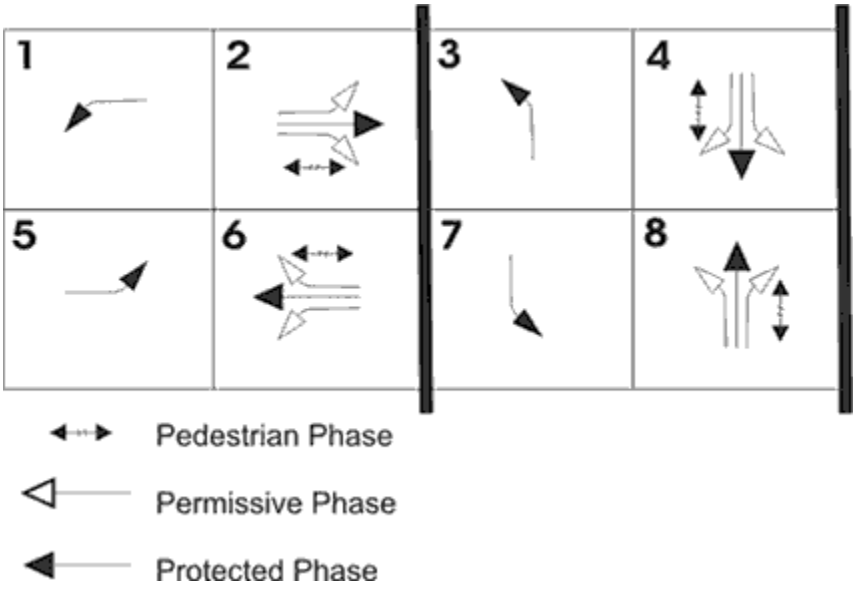


Figure 8. Typical phasing diagram for protected-permissive left-turn phasing

After we understand how left-turn signals work, it is easier to understand the signal head configuration, such as Dallas-Display (Doghouse configuration), FYA.

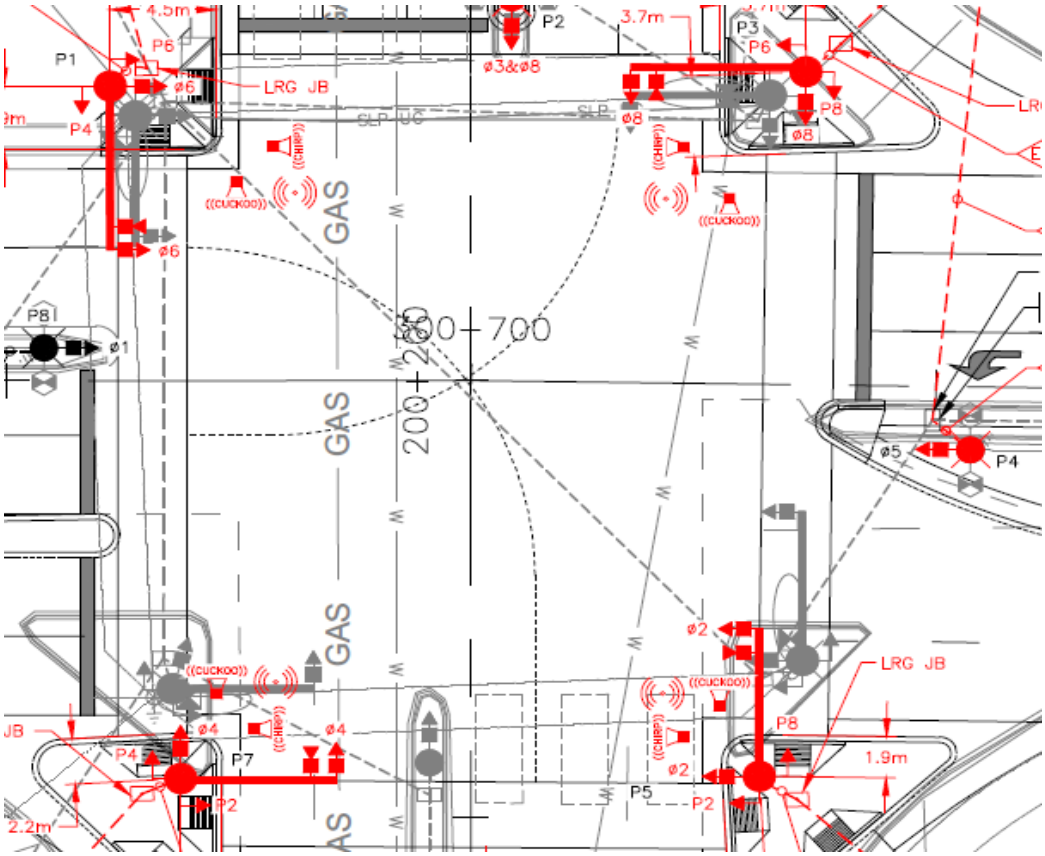
3. Necessity of adding traffic signal head-phasing diagram or table

Phase sequence, channel assignment are already defined in the controller timing plan and database, they can be easily accessed by designers and installers. However, the signal connection from a traffic cabinet's output buss to signal head is usually not clearly defined by the industry, most of the time this part of work is done by the installers based on their experience and judgement. This leaves room for errors and create a safety hazard, so a traffic signal head vs phasing diagram or table is necessary to reduce connection errors and improve public safety here.

1) Here is the enlarged part of the original Figure 3, let's name it Fig 9.

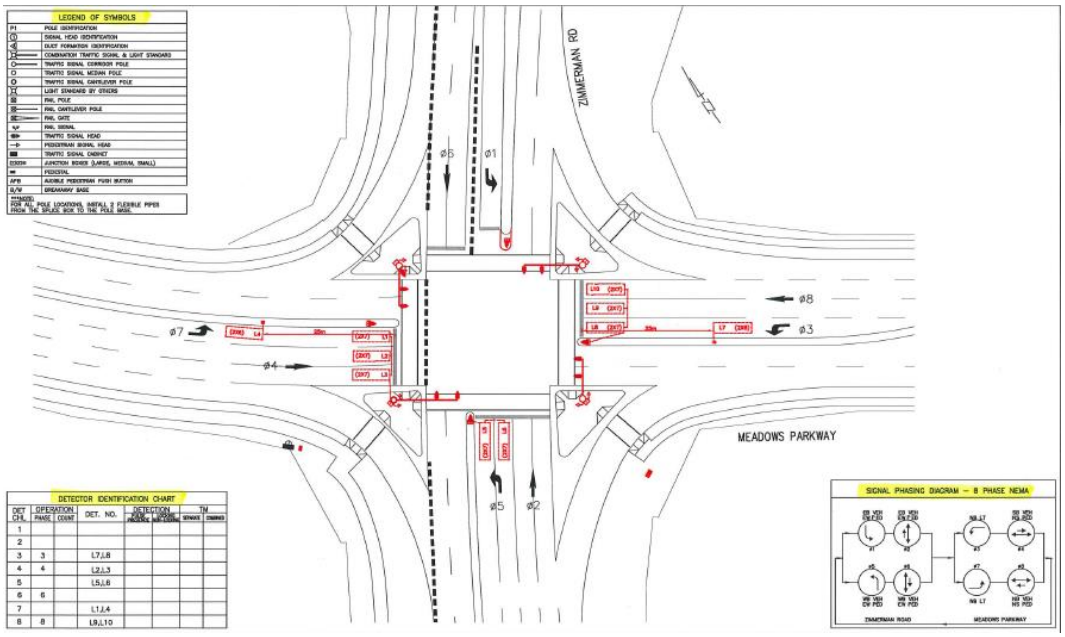
Please see the signal head notation in this diagram. The engineer does not list signal head number here, instead, he uses phase number here! This is a simplified version of signal head vs phase relationship, it is great for professionals to understand what phase will be showing up at that specific signal head! It is simple yet clear! Great job!

Fig 9. 8-phase intersection: Signal Head - Phasing Diagram



2) The above example is great to show phase number in the diagram instead of signal head number. But the face configuration is not listed here, do you know if the engineers want 3 section arrows or 3 section balls? The diagram does not tell you, so a better way is to list everything clearly in a Signal Head vs Phasing Table.
   Let's take a closer look at example 4. Here is the phase diagram again.

   Fig 10. Standard NEMA 8-phase Intersection



   Left-turn phases 1,3,7 are protected-permissive. However due to the dual left turn movement for NBLT, ph5 is fully-protected.

Fig 11 shows the enlarged intersection with signal heads number.

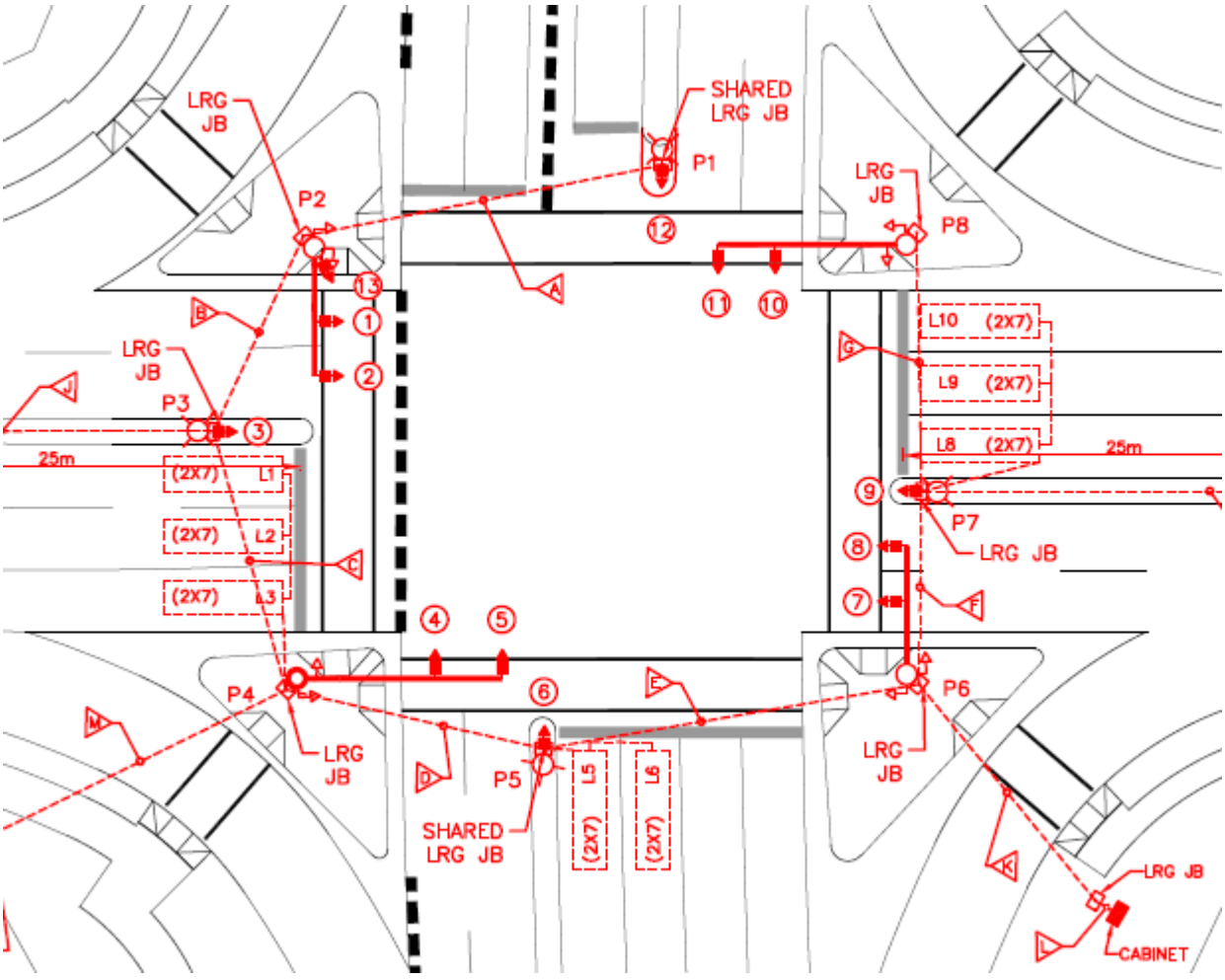


Table 1 is the original signal description table at the bottom of the same drawing.

SIGNAL DESCRIPTION	SIGNALS			BACK BOARD NO.
	PRIMARY	SECONDARY	AUXILIARY	
LED-RD 300 LED-AB 300 LED-GR 300	1,2,4,5,7,8 10,11			1,2,4,5,7,8 10,11
LED-RD 300 LED-AB 300 LED-AR 300				
LED-RD 300 LED-AB 300 LED-GR 300 BI-MODAL 300			3,6,9,12,13	
LED-RD 300 LED-RD 300 LED-AB 300 LED-AR 300				

This table is great to help installers get the ideas of what the engineer wants in the field. We see an error exists in this table: signal heads H12 & H13 should not use “Red Ball, Yellow Ball, Grn Ball, Bi-Modal (Grn/Yellow) Arrow”, as this is usually a protected-permissive signal head setup. H12 & H13 are fully-protected signal heads, so an emphasized “Red Ball, Red Ball, Yellow Ball, Grn Arrow” should be used instead, so H12 & H13 should be in the last row aligned with Auxiliary column.

I tried to improve this table, by adding “driven by phase/overlap” column. And also a column of “Signal Head Arrangement” is inserted. Thus the upgraded version of the table looks like this:

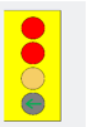
CATEGORY	MODE	SIGNAL HEAD ARRANGEMENT		SIGNALS HEAD DESIGNATION						BACK-BOARD NO.
				PRIMARY	DRIVEN BY PH/OVL	SECON-DARY	DRIVEN BY PH/OVL	AUXI-LIARY	DRIVEN BY PH/OVL	
3 SECTION	PROTECTED THRU		Solid Red Ball	H1,H2	ph8					1,2
			Solid Yellow Ball	H4,H5	ph6					4,5
			Solid Green Ball	H7,H8	ph4					7,8
				H10,H11	ph2					10,11
4 SECTION	PROT/PERM LT (Normally)		Solid Red Ball					H3	ph3&ph8	
			Solid Yellow Ball					H6	ph1&ph6	
			Solid Green Ball					H9	ph7&ph4	
			Dual-Modal Arrow							
	PROTECTED LT CANANA		Solid Red Ball					H12,H13	ph5	
			Solid Red Ball							
			Solid Yellow Ball							
			Flashing Grn Arw							

Table 2. Canadian 3 & 4 Section Head / Phasing Table

The head number column followed by “Driven by Phase/Overlap” column in the table really make it clear for installers, so there is no room left for guessing, and greatly removes the possibility of errors!

If the above intersection is located in USA instead of Canada, similar table can be drawn, the difference is the signal face configuration and the added FYA signal, use of solid green arrow instead of flashing green arrow.

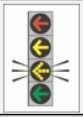
CATEGORY	MODE	SIGNAL HEAD ARRANGEMENT		SIGNALS HEAD DESIGNATION						BACKBOARD NO.
				PRIMARY	DRIVEN BY PH/OVL	SECONDARY	DRIVEN BY PH/OVL	AUXILARY	DRIVEN BY PH/OVL	
3 SECTION	PROTECTED THRU		Solid Red Ball	H1,H2	ph8					1,2
			Solid Yellow Ball	H4,H5	ph6					4,5
			Solid Green Ball	H7,H8	ph4					7,8
				H10,H11	ph2					10,11
3 SECTION	PROTECTED LT		Solid Red Arrow	H12,H13	ph5					
			Solid Yellow Arrow							
			Solid Green Arrow							
4 SECTION	FYA-USA (PROT/PERM LT)		Solid Red Arrow					H3	ph3&Olp2	
			Solid Yellow Arrow					H6	ph1&Olp1	
			Flashing Yellow Arrow					H9	ph7&Olp4	
			Solid Green Arrow							
5 SECTION	DALLAS DISPLAY DOGHOUSE (PROT/PERM LT)		Solid Yel Arrow (Left Middle)					H3	ph3&Olp2	
			Solid Grn Arrow (Left Bottom)					H6	ph1&Olp1	
			Solid Red Ball (Top)					H9	ph7&Olp4	
			Solid Yellow Ball (Right Middle)							
			Solid Grn Ball Louver (Right Bottom)							

Table 3. USA 3, 4, 5 Section Head / Phasing Table

Here is how the overlap is defined:

Olp1=ph1+ph2 Olp2=ph3+ph4

Olp3=ph5+ph6 Olp4=ph7+ph8

3) An extreme complicated situation is the Texas Diamond Interchange. Let's bring back Example 5 for the 4-phase Diamond Interchange. Here are some tables used in the timing chart. Without these tables, it is almost impossible to figure out how all the phases, overlaps, channels, detectors work together.

Fig 12. 4-phase Diamond Interchange

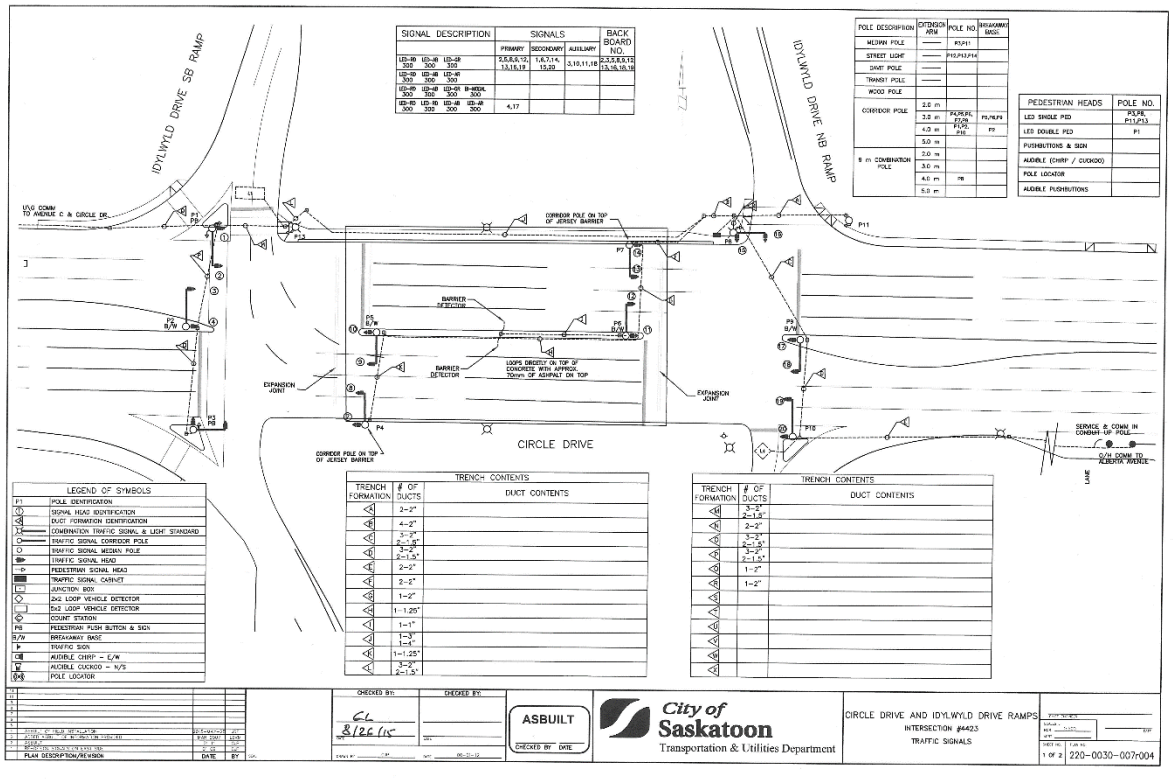


Fig 13. Diamond Interchange Phase/Overlap/Channel Diagram**********Ref 4.2

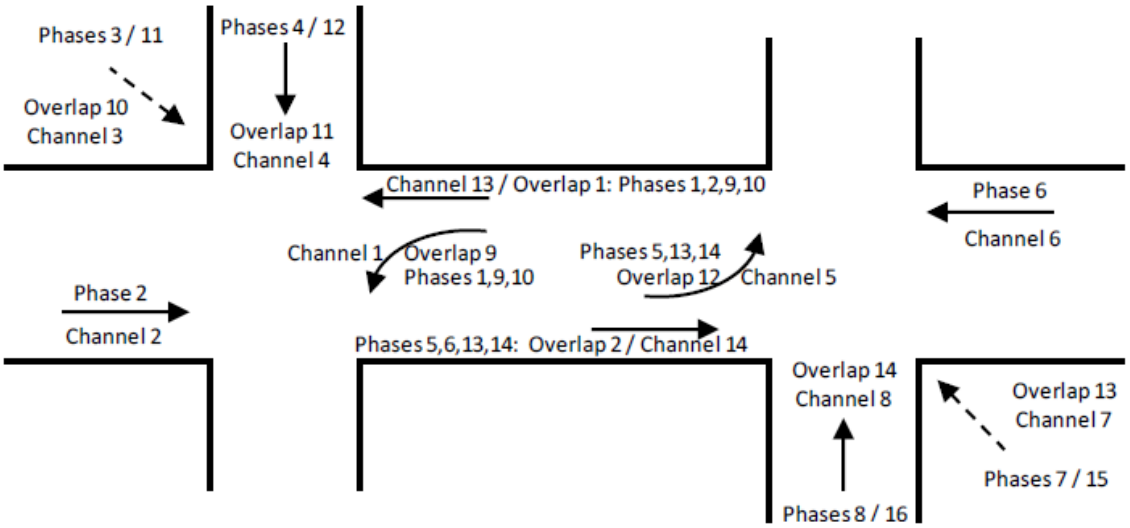
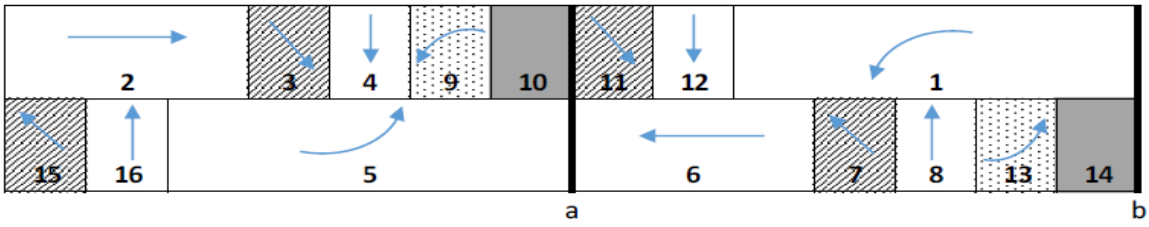


Fig 14. Interchange Phase Sequence **********Ref 4.2



Here are some tables in the timing chart:

Table 4. Diamond Interchange Overlap Setup

Overlap	Enable	Type	Included Phs
1	Enable	Normal	1,2,9,10
2	Enable	Normal	5,6,13,14
9	Enable	Normal	1,9,10
10	Enable	Normal	3,11

11	Enable	Normal	4,12
12	Enable	Normal	5,13,14
13	Enable	Normal	7,15
14	Enable	Normal	8,16
15	Enable	Normal Ped	4,12
16	Enable	Normal Ped	8,16

Table 5. Channel Configuration

Channel	Control Type	Control Source
1	Overlap	9
2	Phase Vehicle	2
3	None	
4	Overlap	11
5	Overlap	12
6	Phase Vehicle	6
7	None	
8	Overlap	14
9	Phase Ped	2
10	Overlap	15
11	Phase Ped	6
12	Overlap	16
13	Overlap	1
14	Overlap	2
15	None	0
16	None	0

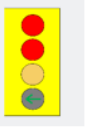
Table 6. Channel Concurrency

Channel	Manual Concurrency
1	5,6,8,10,11,12,13,14
2	5,6,8,9,11,12,13,14
3	
4	5,6,8,10,11,12,14
5	9,10,12,13,14
6	9,10,11,13,14
7	
8	9,10,12,13
9	11,12,13,14

10	11,12,14
11	13,14
12	13
13	14
14	
15	
16	

The last step is to show the signal head / phasing relationship in Table 7.

Table 7.Signal Head / Phasing Table for diamond interchange

CATEGORY	MODE	SIGNAL HEAD ARRANGEMENT		SIGNALS HEAD DESIGNATION						BACK-BOARD NO.
				PRIMARY	DRIVEN BY PH/OVL	SECON-DARY	DRIVEN BY PH/OVL	AUXI-LIARY	DRIVEN BY PH/OVL	
3 SECTION	PROTECTED THRU		Solid Red Ball	H2	Ch13/Olp1	H1	Olp1	H3	Olp1	2
			Solid Yellow Ball	H5	Ch4/Olp11	H6	Ch4/Olp11	H10	Ch2/Ph2	3
			Solid Green Ball	H8	Ch2/Ph2	H7	Ch2/Ph2	H11	Ch6/Ph6	5
				H9	Ch2/Ph2	H14	Ch6/Ph6	H18	Ch14/Olp2	8
				H12	Ch6/Ph6	H15	Ch8/Olp14			9
				H13	Ch6/Ph6	H20	Ch14/Olp2			12
				H16	Ch8/Olp14					13
				H19	Ch14/Olp2					16
4 SECTION	PROTECTED LT CANANA		Solid Red Ball	H4	Ch1/Olp9					18
			Solid Red Ball	H17	Ch5/Olp12					19
			Solid Yellow Ball							
			Flashing Grn Arw							

4. Conclusion

By adding the signal head phasing diagram / table, traffic professionals can avoid unnecessary guesses, the phasing diagram / table provides a much clearer image of the operation of the controllers and traffic signal indications. By doing the little step-by-step change, public safety can be improved, so let's make the change!

5. References

1) “Signalized Intersections: Information Guide”----FHWA Publication Number: FHWA-HRT-04-091 Date: August 2004
   https://www.fhwa.dot.gov/publications/research/safety/04091/04091.pdf
2) Diamond Interchange, examples and figures are excerpted from “Documentation – Programming Diamond Operation”, provide by Tacel.

6. Tables

7. Figures