CHAPTER 4: ACTUATED CONTROLLER TIMING PROCESSES

This chapter includes information that you will need to prepare for, conduct, and assess each of the seven activities included in Chapter 4 of the student activity book. Figure 1 shows the various files that are available to support your works as you use these activities, including mini-lecture slides, solution files, and student resource files.

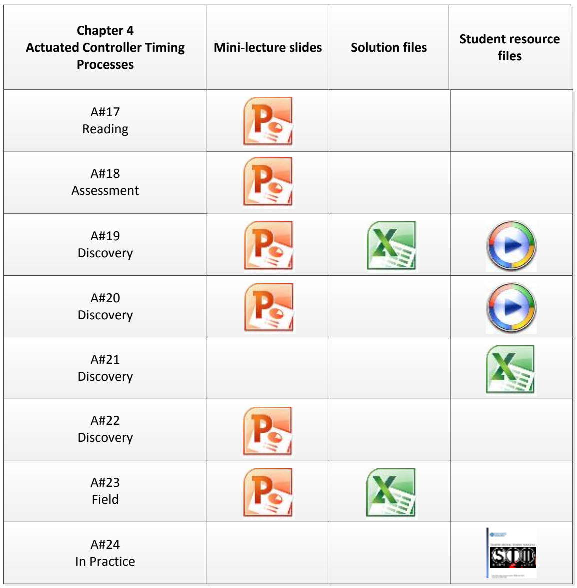


Figure 1. Support files

Figure 2 shows the kind of work required for each activity, how the activities might be grouped, and the approximate amount of class time required to complete the activity. The figure also identifies whether there is homework involved, a mini-lecture could be presented, student discussion could take place, and group work to do.

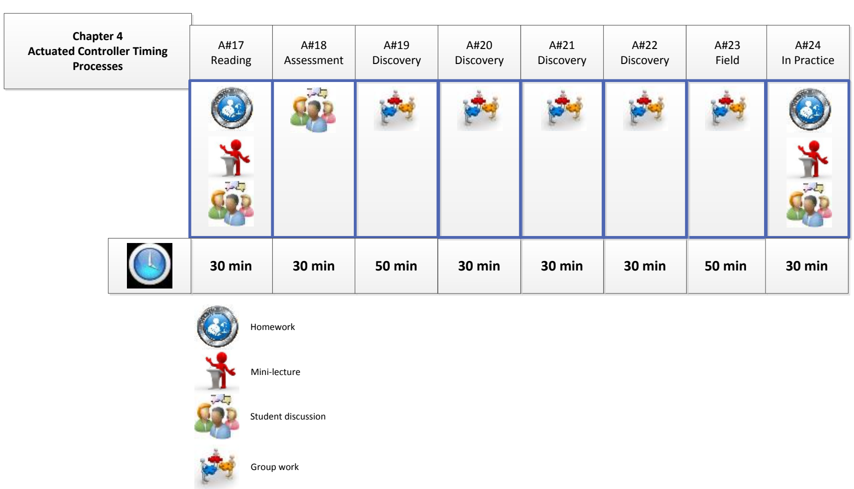


Figure 2. Activity work

Using Activity #17: Controller Timing Processes (Reading)

Overview
This activity requires the student to read the “Information” section, define the terms listed in the Glossary, and answer the “Critical Thinking Questions.” Students will learn about the fundamental elements of the ring barrier diagram, including the conflict matrix, concurrency groups, and ways of handling various sets of compatible and conflicting movements.

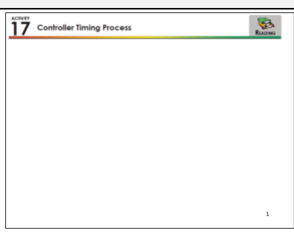
Options for Use
The reading, defining the terms in the glossary, and answering the critical thinking questions are usually done as homework. After the students complete this work, the instructor has several options for assessing and clarifying student understanding of the reading during class:

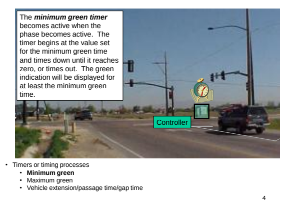
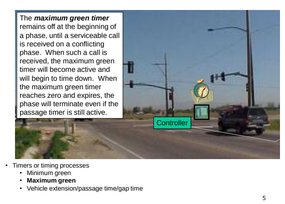
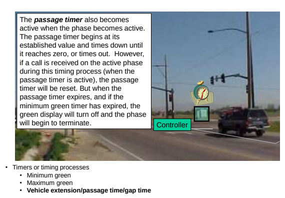
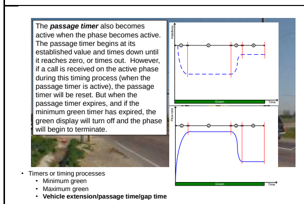
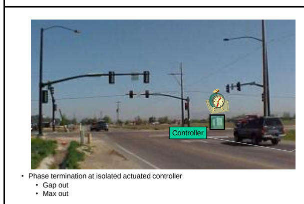
- Quiz to assess their understanding and to hold them accountable for the reading. (15 minutes)
- Discussion and synthesis of the answers to the quiz, the glossary definitions, and answers to the critical thinking questions. (30 minutes)
- Doing a mini-lecture on the key points of the reading
- Moving directly to Activity #18 in which students can assess their understanding of the reading and share what they know with other students in the class.

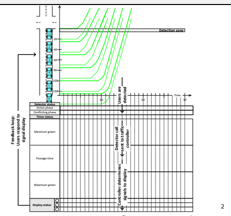
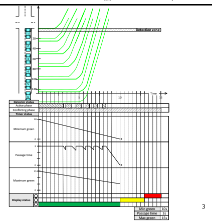
Preparing for the Activity

- Decide which of the options you want to use during class.
- Prepare for the class by reviewing Activity #13, including the “Information”, the Glossary, and the Critical Thinking Questions.
- Review the example script included below.

Doing the Activity (Script)
[Slides: slides17.pptx]
You can use all or part of the following script and slides to conduct this activity.

Slide	Text
	As you read these materials, pay special attention to the timing parameter definitions, the timing parameter values or settings, and the timing processes themselves. Consider how these definitions, values/settings, and processes fit into our overall model of the traffic control system (users, detectors, controllers, and displays) that we considered in chapter 1 (Activity #1).
	In chapter 3, you learned about the sequence of phases, and the movements controlled by the phases. Today, we will look at the operation of a phase and the processes that are involved in this timing unit. [sketch of three timing intervals] Each of these intervals is distinct, and during each interval, the display or indication remains unchanged.

<table>
<tr><th>Slide</th><th>Text</th></tr>
<tr><td></td><td>Considering the timing process for yellow or red clearance. It is a very simple process: [sketch on board the value of timer vs time for yellow timer. The timing parameter value is Y=3. The current value of the timer (from 3 to 0), and how the timer works (linear and constant rate decline).</td></tr>
<tr><td></td><td>For green, we have several timers or timing processes to consider. For basic actuated control, there are three processes: minimum green, passage time or vehicle extension time, and maximum green time. Each is a parameter value, each also has an associated timing process.</td></tr>
<tr><td>
</td><td>The minimum green time (draw on board): value, timing process (draw on board: starts at beginning of phase/green indication and times down in a linear manner until it reaches zero.)</td></tr>
<tr><td>
</td><td>Maximum green timer. Purpose is to maintain maximum cycle length value. Timing process: maintains initial preset value until conflicting call is received (call on conflicting phase); once conflicting call is received, it times down in linear manner until it reaches value of zero. [draw on board]</td></tr>
<tr><td>
</td><td>The passage time or vehicle extension time: purpose is to extend green until a gap of a pre-determined size (equivalent to what we will call the maximum allowable headway, or the largest headway that you are willing to tolerate in the departing queue) is reached. The timing process: as long as a call is active (vehicle is in detection zone), timer remains at preset value of the timing parameter itself, when call is dropped (inactive), timer times down in linear manner. It will be reset before it reaches zero, if a new call is received. It will time down to zero if no new call is received.</td></tr>
<tr><td>
</td><td>This slides the flow profile and headway profile diagrams during the queue clearance process and afterwards and identifies time segments in these profiles that correspond to when we want the green (phase) to continue to time.</td></tr>
<tr><td>
</td><td>The three timing processes control the timing of the phase. Together they determine when the phase will end.
Logic for phase timing/termination (conditions):
• Gap out when minimum green and passage timers reach zero.
• Max out when maximum green timer reaches zero.</td></tr>
</table>

Slide	Text
	We can represent the timing processes in the context of the traffic control process diagram which we learned about earlier.
	This version of the traffic control process diagram shows the trajectories of six vehicles in a departing queue at the beginning of green, the resulting status of the active phase detector (and assumed conflicting phase detector status), the three timers as they respond to the detector states, and finally the resulting signal display status. These results assume a minimum green time of 10 seconds, a passage time of 3 seconds, and a maximum green time of 15 seconds.

Solutions

The solutions presented here include glossary definitions, critical thinking questions and answers, and notes for the quiz.

Glossary Definitions

Term	Definition
Gap out	A type of phase termination and occurs when both the minimum green timer and the passage timer have expired.
Max out	A type of phase termination and occurs when the maximum green timer expires.
Maximum green	The maximum duration that the green will be displayed after a call has been received on a conflicting phase.
Minimum green	The minimum time that the display will remain green for a phase no matter what else occurs.
Passage time	The maximum time that a detector can remain unoccupied before the passage timer expires.

Critical Thinking Questions and Answers

1. What are the two types of phase termination and what are the factors that result in each of these two types?
- A gap out occurs when both the minimum green timer and the passage timer have expired. A max out occurs when the maximum green timer expires.
2. What happens if the passage timer expires before the minimum green timer expires?
- Since both of these timers must expire before the phase can terminate, the phase will continue timing until the minimum green timer expires. The phase will terminate at this point.

3. What is a traffic control process diagram and what processes does it illustrate?

- A traffic control process diagram shows the four components of the traffic control system (the user, the detector, the controller, and the display) and the way that they are interconnected.

Quiz questions and answers

The purpose is to check understanding of basic controller timing concepts.

1. For each of the three basic actuated timing processes, define: when the timing process starts and how the timer functions.

- The minimum green timer begins to time at the beginning of the phase and times down in a linear manner until it reaches zero and expires.
- The passage timer maintains its initial parameter value as long as a call is active; it times down when the call is dropped (a vehicle leaves the detection zone); it can be reset if another vehicle enters the detection zone (call is again active)
- The maximum green timer begins timing when a call is received on a conflicting phase; it continues to time down in a linear manner until it expires.

2. Describe the condition or conditions that must be true for each of the two phase termination processes.

- A phase gaps out (terminates) when both the minimum green timer and the passage timer have expired.
- A phase maxes out when the max green timer expires.

Using Activity #18: What Do You Know About Controller Operations? (Assessment)

Overview
In this activity, students will learn about actuated intersection timing parameters like minimum green, passage time, and maximum green, and how they operate. The purpose of this activity is to assess students' understanding of actuated timing processes. By the end of the activity, students should be able to articulate how the timers for minimum green, passage time, and maximum green work, the conditions necessary for each timer to be active, and how vehicles, detectors, and the signal display interact with the timers. These interactions were summarized in chapter 1 in the following four ways:

- The user arrives at the intersection and is detected.
- The detector sends a call to the traffic controller.
- The controller determines the signals to display based on a series of timing process and phase termination logic.
- The user responds to the signal that is displayed.

Activity #18 uses plots to show these interactions.

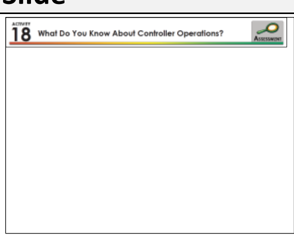
Options for Use

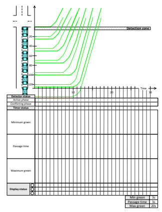
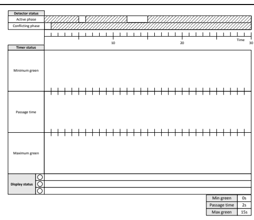
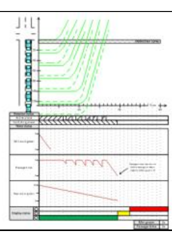
- Completion of tasks by individual students during class.
- Discussion of responses to questions.

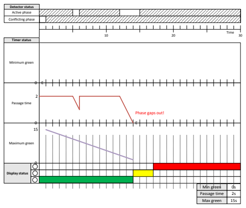
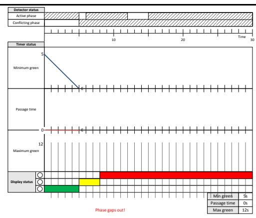
Preparing for the Activity

- Confirm options for class period.
- Review questions and answers.
- Consider how you might engage students after they have completed the activity, reinforcing and clarifying what they have learned.

Doing the Activity (Script)
[Slides: slides18.pptx]
You can use all or part of the following script to introduce and conduct this activity.

Slide	Text
	[Included detailed explanation of detection zone process and other processes to orient them to this activity.]

Slide	Text
	This activity gives you experience in controller operations. The activity has two tasks, both related to what we call the traffic control process diagram and each dealing with a scenario of traffic flow and timing settings. A TCPD shows the relationship between the four components of the traffic control system that we've discussed before, but with more specifics. Here is one of the diagrams. The vehicle trajectory data shown in the time space diagram and the timing parameter values (bottom right) are shown in the Traffic Control Process Diagram. Draw the detector status, the timer status, and the display status. Show the graphs for the values of the three timing processes in the spaces providing, noting the maximum and minimum values of the processes on the y-axis. The resulting signal display may change some of the vehicle trajectory plots. Note on the figures where you think that these changes will occur. Assume a yellow time of 3 seconds. Assume also that the conflicting call begins at t = 0 and continues throughout the green duration.
	Here is the second diagram showing Traffic Control Process Diagrams without the vehicle trajectories, but with the detector status data for both the active and the conflicting phases. The values of the timing parameters are given in the lower right of the two figures. Show the resulting timing processes in the form of a chart showing the value of the timing parameter as long as the green is active for that phase. Show the resulting signal display status, noting only when the display changes. State how the phase terminates in each case. Assume a yellow time of 3 seconds.
	Let's take ten minutes to complete these diagrams with a partner. [call on students to discuss results]
	Note: Of the two ways in which a phase can end (gap out and max out) this activity does not require students to prepare timing process control diagrams for any max out terminations. Therefore, it is important to cover the conditions necessary for a phase to max out in lecture.
	Here is the result for Task 1.

Slide	Text
	Here is the first of the results for Task 2
	Here is the second of the results for Task 2.

Solutions
The solutions are shown above and in the PowerPoint file [slides18.pptx].

Other Notes
There are several issues that students typically encounter when learning about signal timing processes that the instructor could address in lecture.

- One issue is that if a the passage timer reaches zero, but the minimum green timer has not, the phase will continue to time until the minimum green timer expires, at which time the phase will terminate. Conversely, if the minimum green timer reaches zero, but the passage timer has not, the phase will continue until both timers are at zero.
- Students are often confused by the maximum green timing process. The maximum green timer does not begin to time until there is a vehicle detected in a conflicting movement. Once a conflicting call has been placed, the maximum green timer will begin to time. If the maximum green timer reaches zero, the phase will terminate regardless of the status of the passage timer.

Helpful Hints

- Clarify: when call is active: when vehicles enter the zone and dropped when vehicles leave zone.
- Common student misconception: Confusion on difference between occupancy and occupancy time. Most thought that occupancy was a time period as well instead of state of detector.
- Misconception: Not everybody included both passage time and min green in what defines a gap out. There was also confusion on the two types of phase termination.

Reflections
Some other student questions to consider:

1. Can we have PT = 0; if so when?
2. Can we have a minG = 0?
3. What happens when the passage time expires before the minimum green timer?

Using Activity #19: The ASC/3 Traffic Controller (Discovery)

Overview

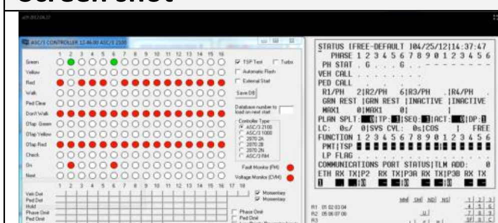
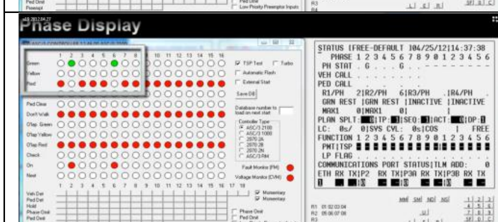
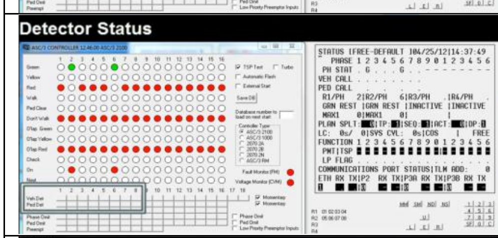
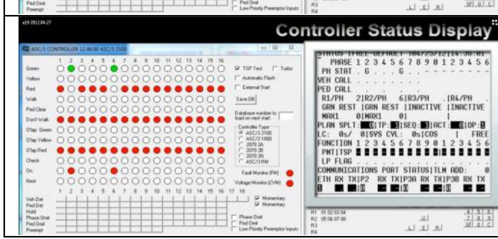
In this activity, students will learn about a traffic controller (here, Econolite's ASC/3 controller) and how it responds to various inputs. It is a challenging activity in that students will have to learn where various information is located on the controller tester screen and to observe the effects of the various inputs (detector calls) on the timing processes.

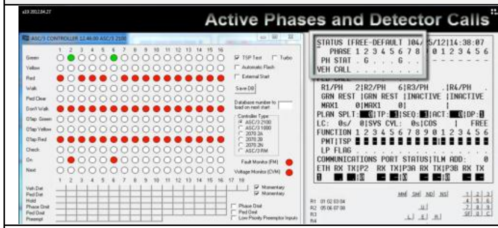
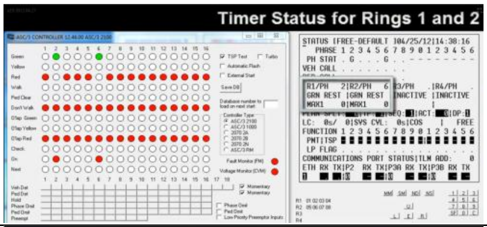
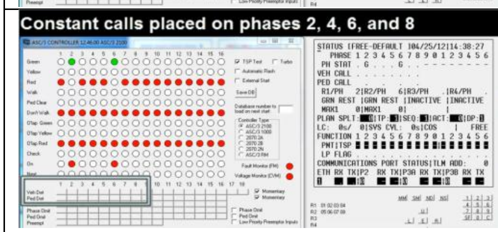
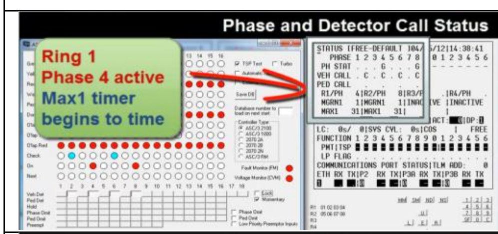
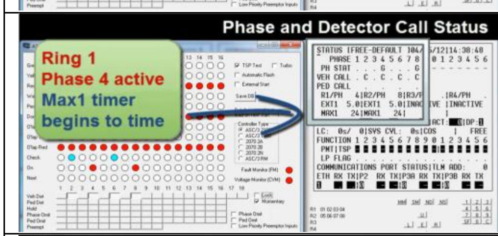
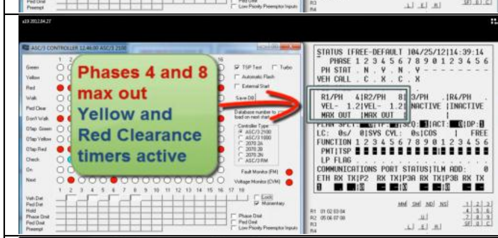
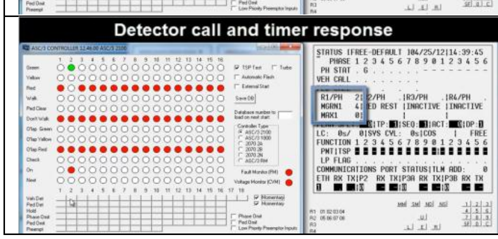
Options for Use

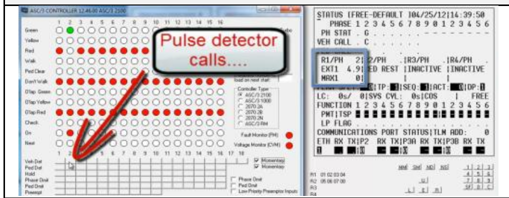
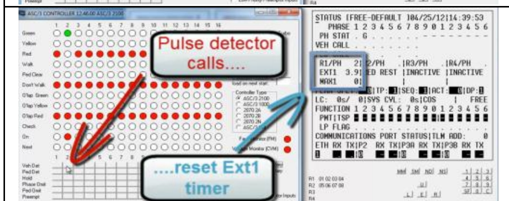
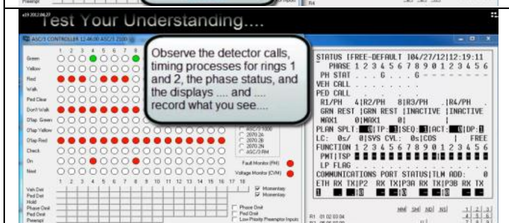
This activity is best done during class when the instructor can interact with students when questions arise.

Preparing for the Activity

The best way to prepare for this activity is to watch the video and note some of the important parts that relate to what the students will be observing. The following script should help in this preparation.

Screen shot	Timing	Description
	0:00 – 0:05	**ASC/3 Display and Detector Status**
	0:05 – 0:15	**Phase Display** Box drawn around green, yellow, red displays
	0:15 – 0:24	**Detector Status** Box drawn around "Veh Det" in lower left of screen
	0:26 – 0:35	**Controller Status Display** Box drawn around the status display

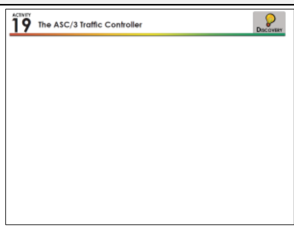
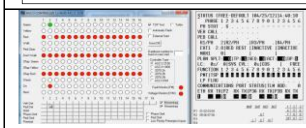
Screen shot	Timing	Description
	0:36 – 0:45	**Active Phases and Detector Calls** Box drawn around phase status and vehicle call area of status display screen.
4- 	0:46 – 0:55	**Timer Status for Rings 1 and 2** Box drawn around ring 1 and ring 2 timing data on status display screen.
	0:58 – 1:12	**Constant calls placed on phases 2, 4, 6, and 8** Box drawn around suitcase tester where vehicle calls are placed. Calls are placed on phase 8 first, followed by phases 6, 4, and 2.
	1:13 – 1:20	**Phase and Detector Call Status** In response to these calls (which are locked): phases 4 and 8 are active.
	1:21 – 1:47	**Phase and Detector Call Status** Max1 timer times down.
	1:48 – 1:58	Yellow and red clearance timers active and time down; phases 4 and 8 end.
	2:00 – 2:07	**Detector call and timer response**

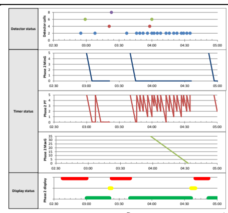
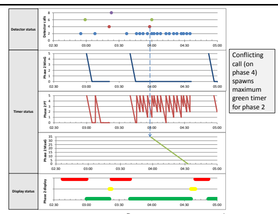
Screen shot	Timing	Description
	2:08 - 2:11	**Detector call and timer response** Phase 2 pulse detection (2:08); Ext1 timer reset.
	2:11 – 2:30	**Detector call and timer response** Phase 2 pulse detection (2:10); Ext1 timer reset. Similar pulse detections: 2:13, 2:16, 2:19, 2:23, 2:24, 2:28
	2:38 – 5:05	**Test Your Understanding** (See table below for status data) Status at t=2:38: phases 4 and 8 rest in green
	2:40 – 3:15	Phase 2 call at 2:55 Phase 6 call at 2:59 Result: Phases 4 and 8 gap out at 2:55 Phases 2 and 6 green at 3:00 Minimum green expires Phases 2 and 6 rest in green Phase 2 call at 3:08, phase 2 timer reset Phase 2 rest in green at 3:14
	3:15 – 3:30	Phase 4 call at 3:21 Phases 2 and 6 gap out at 3:21 Phase 8 call at 3:23
	3:30 – 3:40	Phase 2 call at 3:37
	3:40 – 4:40	Various phases 2, 4, and 6 calls between 3:46 and 4:35 Phase 2 min green expires at 3:45 Phase 2 extension time times and resets between 3:46 and 4:35 Phase 2 maximum green timer begins at 3:58; expires at 4:36 and phase 2 maxes out Phase 4 green at 4:40 Phase 4 gap out at 4:46 Phase 2 green at 4:52 Phase 2 green rest at 4:57

The following data summary based on video observation might be helpful to review in preparation for conducting this activity.

	Vehicle Call				Phase Status				Ring 1				Ring 2			
Time	2	4	6	8	2	4	6	8	Active Phase	Min	Ext1	Max1	Active Phase	Min	Ext1	Max1
2:38						G		G	4-rest				8-rest			
2:55	C				N	Y		Y	4-gap out				8-gap out			
2:59			C		N	R		R								
3:00					G		G		2	4			6	5		
3:05					G		G		2-rest				6-rest			
3:08	C				G		G		2		5					
3:14					G		G		2-rest				6-rest			
3:21		C			Y	N	Y		2-gap out				6-gap out			
3:23				C												
3:26						G		G	4	5			8	5		
3:31									4-g rest				8-g rest			
3:37	C				N	Y		Y	4-gap out				8-gap out			
3:40					G											
3:42							Y		2	5			6	5		
3:46	C								2		5		6-rest			
3:49	C								2		5					
3:52	C								2		5					
3:56	C								2		5					
3:58		C							2		2.6	35				
4:00	C		C						2		5	33				
4:02	C								2		5	30				
4:05	C								2		5	28				
4:08	C								2		5	25				
4:13	C								2		5	21				
4:16	C								2		5	18				
4:20	C								2		5	15				
4:23	C								2		5	12				
4:27	C								2		5	8				
4:29	C								2		5	7				
4:32	C								2		5	4				
4:35	C								2		5	1				
4:36					Y	N	N		2-max out			0	6-gap out			
4:40						G	G	G	4	5			8-r rest			
4:46						Y	Y	Y	4-gap out							
4:52					G				2	5						
4:57					G				2-g rest							

Doing the Activity (Script)
[Slides: slides19.pptx]
All or part of the following script can be used to conduct the activity.

Slide	Text
	So how does a controller work? In this activity, you will see how a controller works, specifically a software version of Econolite's ASC/3 controller.
	[open ASC/3 movie file] – Pause. This is what is known as a suitcase tester, where an engineer or technician places inputs into the controller. This is exactly like what happens in the field when a vehicle or pedestrian places a call to the controller. Let's look at this screen to see what is there before your start to work. • Explain the suitcase tester on the left. • Explain the controller status screen on right. Explain the video timeline: The video has three parts. The first shows the basic layout of the controller status display screen and suitcase tester screen, some examples of detector calls and responses, and finally a chance for students to test their skills in which they have to link the detector calls that they observe with a result from the controller.
	The first part of the video shows the basic layout of screen and key items (0:00-0:55) Start video. Pause and explain each of the following segments: • 0:00-0:15: display status • 0:15-0:24: vehicle detector input • 0:26-0:35: status display • 0:36-0:45: phase status and vehicle call area • 0:46-0:55: ring 1 and ring 2 timing data
	Example detector calls and controller/display responses with visual tags (0:55-2:30)
	Testing your skills: trying to link detector calls with controller and display responses (2:40-5:00)

Slide	Text
	Read information, then start tasks. Record your observations in table on page 119. [see movie script presented earlier in this activity]
	Discuss results (see “script” file)
	This chart shows the detector, timing, and display data for phase 2. Note that the maximum green timer for phase 2 is spawned by the detector call on phase4 (one of the conflicting phases) at t = 3:58.
	This slide focuses on how the conflicting call on phase 4 spawns the maximum green timer for phase 2.

Solutions

This section includes critical thinking questions and answers, other questions that you might use with students to encourage discussion, and sample answers from students from past classes.

Critical Thinking Questions and Answers

1. What are examples of the information provided in the controller status display screen?
- Detector status
- Max Green Timer
- Min Green Timer
- Passage Timer
- How the phase terminated

2. How many rings can be accommodated by the ASC/3 controller?
- The ASC/3 controller can accommodate 4 rings

3. How do you know whether a gap out or a max out has occurred?
- The status display screen shows these phrases when either occurs.

4. How can you verify that a vehicle call has been placed?
- Visually check to see if a vehicle is on the appropriate detector, or watch how the timing parameters change. For example check to see if the passage timer was reset.

5. Describe some of the observations that you have made on the response of the controller timing processes to vehicle calls.

- [see notes below]

Other questions that you might use (and answers)

1. How is a vehicle call displayed?
- “C” is used to display a call

2. Gap out vs max out
- During the yellow and all red time, this controller displays how the phase ended where the max green timer would be.

3. Which screen shows the status of the phasing and timing processes?
- Controller status screen

4. Where are the timing parameters stored?
- The timing parameters are stored in the ASC/3 controller Editor under controller.

Sample answers to questions from students

The following information provides you with the perspective of how students in previous classes have answered the Critical Thinking Questions.

1. What are examples of the data provided in the controller status display screen?
- -Max timer
- -Passage timer
- -Call status
- -Green status
- -Veh Call
- -Rings
- -Red/Yellow Timer

2. How many rings can be accommodated by the ASC/3 controller?
- 4 rings
- 4, this video only had 2 active

3. How do you know whether a gap out or a max out has occurred?
- It tells you when it gaps out or the max timer says 0.
- There are two separate timer indications, one for the passage time and one for the max time, from watching these you can tell if the timer maxes out or gaps out.
- The display tells you if you have one with (max out or gap out) at the beginning of yellow

4. How can you verify that a vehicle call has been placed?
- Under the veh call there is a variable to show indication of a vehicle
- In the controller display it shows what the controller sees from the detectors.

5. Describe some of the observations that you have made on the response of the controller timing processes to vehicle calls.

- Phase 2 was serviced the most because passage timer would not expire and max timer would expire to change to green for 4
- The controller reacts instantly to whatever is selected in the suitcase tester. The max out time did not start until a vehicle call happened in a conflicting phase.

Other notes from student responses

- Some of the data provided in the controller status display screen was: phase change factors, max times, phases active, and phases non-active.
- The ASC/3 controller can accommodate up to four rings but it was only using two.
- We know a gap out or max out has occurred because the controller status display tells us.
- We can verify that a vehicle call has been placed because it shows on the detector status next to the vehicle detector switch.
- Some observations that we have made on the response of the controller timing processes to vehicle calls were that whenever a call is placed on an active phase, the green time is extended. We also noticed that the max out time was only maxed out once to many calls were made on an active phase.

Two example student table with notes on video observations

Video Time Interval	Detector Calls	Controller Responses/other notes
0:00-0:55	None	2&6 are green
0:58-1:12	2,4,6,8	2&6 yellow
		4&8 green-1:09
1:13-1:20	2,6	Max out timer begins (32 seconds)
		Timer maxes out, 4&8 turn yellow
		2&6 turn green
		6 times out, turns red
		Passage timer for 2 keeps it green
2:40-3:00	Call on phase 2 at t=2:55	4&8 start green
		when call at 2, 4&8 turn red, 2 &6 turn green
3:15-3:30	Call on phases 4 and 8 at t=3:21-3:37	start with 2&6 green
		when call at 4&8, 2&6 turn red, 4&8 green
		4&8 rest on green
3:30-3:40	Call on phase 2 at t=3:37	2&6 turn green
		min green timer begins
3:40-4:40	Calls on phases 2, 4, and 6 between t=3:46 and 4:35	Call on 4 but has to wait until max green time on 2 expires since passage time is not timing out
		2 maxes out, 4 gets serviced
		Call at 2, 4 gaps out, 2 gets service

Video Time Interval	Detector Calls	Controller responses/other notes
0:00 -0:55	None / Intro	2 & 6 are green
0:58 - 1:12	Call on 2,4,6,8	2 & 6 turn yellow, min green timer ends
1:13 - 2:30	Detector calls turned off and pulse detector 2	Phase 4 is active, max timer begins
1:48 phase 4 & 8 max out		
(2s) yellow and (3s) red timers activate		
2:10 -2:30 Extension timer resets		
2:40 - 3:00	Call on phase 2 @ t = 2:55	Phases 4 and 8 start yellow and red times

Using Activity #20: How A Traffic Phase Times and Terminates (Discovery)

Overview
In this activity, students will learn how a controller responds to changes in traffic demand and continue to build their understanding about the minimum green, maximum green, and passage timers. They will observe the signal timing process of a traffic controller responding to traffic demands in a video. Students will observe the southbound approach (phase 4) of the intersection of State Highway 8 and Line Street in Moscow, Idaho. The southbound Line Street approach has two lanes, a left turn lane and a through/right turn lane. State Highway 8 is the major street and serves as the primary east-west route through the city. It also serves as the major access to a university, located south of the intersection. Students will monitor traffic on the through/right turn lane of the southbound approach. By the end of the activity, students should understand how the controller responds to changes in traffic demand. Students should also observe how the minimum green, passage time, and maximum green timers function within the controller.

Options for Use
While this activity can be used as homework, doing the activity in class allows for the instructor to monitor their observations and discuss their results with them and the rest of the class.

Preparing for the Activity
[Captioned movie file: a20 supplemental video.mp4]
In Activity #20, students watch a video and, through their observations, learn about how a traffic phase times and terminates. The video, which lasts about 3.5 minutes, shows an aerial view of a simulation of traffic flow at a signalized intersection.

- Two side by side views of identical intersections are shown.
- The focus is on the southbound approach, which is controlled by phase 4.
- The southbound approach has a 22 foot presence detector located at the stop bar.
- The timing parameters are:
- Minimum green time = 5 seconds
- Vehicle extension time = 2.5 seconds
- Maximum green time = 20 seconds
- The only difference between the two views is the traffic volume on the southbound approach. The left view has an initial queue of two vehicles while the right view has an initial queue of five vehicles.

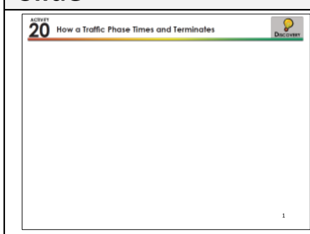
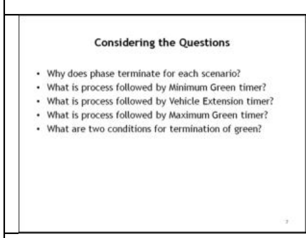
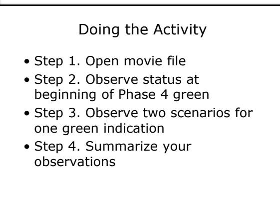
The key point is the timing of the phase is dependent not only on the timing parameter values that have been set and the length of the detection zone, but as we see in this video, the vehicle demand. When the volume is lower (as in the left view), the phase gaps out. When the volume is higher (as in the right view), the phase maxes out.

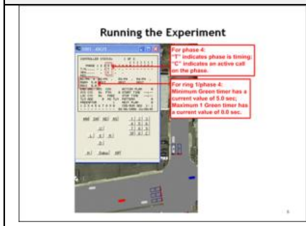
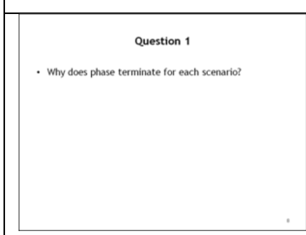
Following is a script that you can review as you watch the supplemental video to get a better feel for its content:

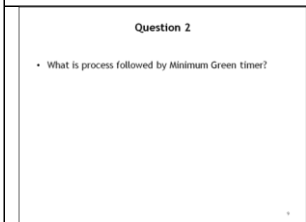
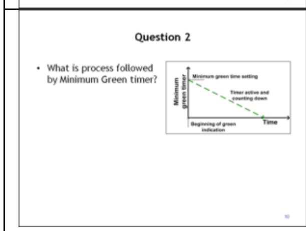
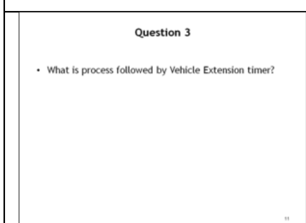
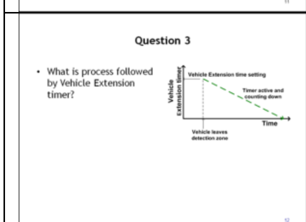
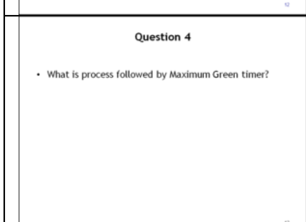
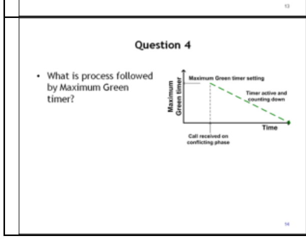
Video (sec)	Script
0:00	The video for lesson 1 shows two cases, an aerial view of two intersections, side by side. The physical aspects of both intersections are the same. All timing data and the detection systems are the same. The detection zones are 6 feet wide and 22 feet long, and are located at the stop bar. Only the traffic flow conditions are different. The simulation clock reads 41.4 seconds. The simulation will be running in slow motion, at 20 percent of real time.
0:29	Queues form on the southbound approach. Two vehicles are in queue in the left window and five vehicles are in queue in the right window. The display is red for phase 4, the phase serving the southbound through movement.
0:41	The signal control status display shows the following information. • A call is active on phase 4, but the phase is not currently timing • Phase 2 is timing in ring 1 and phase 6 is timing in ring 2 • Phase 2 has just gapped out
0:54	We will now shift our attention to the left window where a queue of two vehicles has formed on the southbound through lane during red.
1:02	The display changes to green and the two vehicles in the queue begin to move. The minimum green timer begins to time down.
1:09	Shortly after the beginning of green a call is received on phase 2 (one of the conflicting phases), so the maximum green timer becomes active and begins to time down.
1:19	When the simulation clock reads 50.6 seconds, both vehicles have entered the intersection. The detection zone becomes empty, and the call is dropped on phase 4. The vehicle extension timer begins to time down when the call is dropped.
1:32	When the simulation clock reads 52.6 seconds, the vehicle extension timer expires, and as a result, the phase gaps out. Yellow now displays for phase 4.
1:42	We will now shift our attention to the right window. The southbound through lane has a queue of nine vehicles that formed during red. The phase 4 display has changed to green and the queue began to move. The minimum green timer starts at 5 seconds and is timing down.
1:57	The minimum green timer expires when the simulation clock reads 56.4 seconds. The vehicle extension timer is now displayed, with a starting value of 2.5.
2:07	Since there is a call on phase 6, the maximum green timer also begins to time down.
2:14	The southbound queue continues to move along the approach and enter the intersection. The vehicle extension timer begins to time down when the call is dropped (when there are no vehicles in the detection zone) but the timer continues to be reset to 2.5 seconds when the next vehicle enters the detection zone.

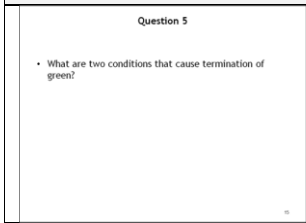
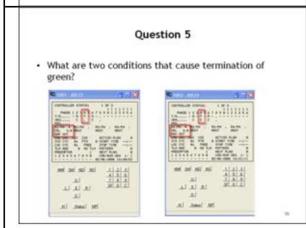
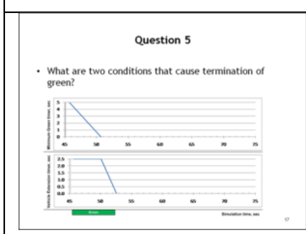
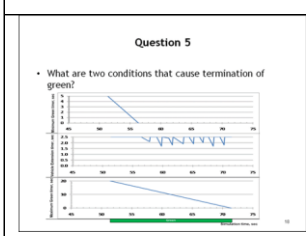
Video (sec)	Script
2:31	The vehicle extension timer times down to 1.8 seconds and is reset again to 2.5 seconds when the next vehicle enters the detection zone.
2:39	But another process also continues, that is the maximum green timer. The maximum green timer started when a call was received on a conflicting phase. It started at 20 seconds and now is at 6 seconds.
2:54	These parallel processes continue as the queue continues to be served. A vehicle enters the detection zone, the vehicle extension timer is reset. A vehicle leaves the detection zone and the vehicle extension timer begins to time down. All the while the maximum green timer continues to time down.
3:11	While there are now five vehicles on the approach, the last vehicle in the original queue enters the detection zone and then the intersection. The maximum green timer is down to one second.
3:21	The queue is still clearing when the maximum green timer expires when the simulation clock reads 71.4 seconds. The phase "maxes out." Yellow is now displayed for phase 4.

Doing the Activity
[Slides (a20.pptx)]
Slides and the following script are available to use as you introduce and conduct the activity.

Slide	**Text**
	[Review with the students the Purpose, the Learning Outcome, the Required Resources, and the Deliverable from Activity #13.] **Tell**: Remember the learning outcome for this lesson: Be able to describe the two primary methods for the termination of a traffic phase at an isolated intersection [In this activity, the southbound approach (phase 4) is the subject approach.]
	[Before the students begin the activity, they need to read the "Questions" that they will answer when they are done with their observations. These questions should be kept in mind as they conduct their observations.]
	[Review and summarize each task that they will complete as part of this activity. It may be helpful to write a one sentence summary of each task on the board.] **Tell**: Read through the instructions before beginning the activity.

Slide	Text
	[One of the most important aspects of this course is to learn to observe traffic flow conditions, the status of the detectors and signal displays, and the status of the controller timing processes. This slide shows this information and helps to focus the student on what is important.] **Tell**: Open the movie file, and then pause for a moment to look at the screen and see what you can observe. Note that there are always four kinds of information presented: • The traffic flow conditions • The status of the detectors (active or off) • The status of the controller and the various timing processes • The status of the signal display (red, yellow, green) **Ask**: What do you see in this slide? **Possible responses**: (1) the phase that is timing, noted with a "T", (2) the phases on which there are active vehicle calls, noted with a "C", (3) the phases that are timing for each ring, and (4) the values of the currently active timing processes, here the minimum green timer and the maximum green timer. **Tell**: You can now complete Activity #0. When you have completed step 3, write down your observations. Review the "Questions" with your partner (if you are working with a partner) and write your answers. Be ready to share and discuss your answers with the rest of the class. [Allow them about 5 minutes to complete the activity]
	[Consider question 1 and encourage the students to think about it and to consider their answer.] [For an isolated signalized intersection, phases can terminate in two ways. • A phase will gap out when the vehicle extension timer (VEXT) times down to zero, after the minimum green timer (MGRN) has timed down to zero. The vehicle extension timer begins to time when the call on the phase is inactive (dropped). The minimum green timer begins to time when the phase becomes active. • A phase will max out when the maximum green timer (MAX1) times down to zero. The maximum green timer begins to time when a call on a conflicting phase is received.] **Ask**: why does the phase terminate for each scenario?

Slide	Text
	Answer: In the first scenario, the phase terminated because the Vehicle Extension timer expired ("gapped out"). In the second scenario, the phase terminated because the Maximum Green timer expired ("maxed out").
	**Ask**: What is the process followed by the Minimum Green timer from the beginning of the green indication, until the timer expires? [Give them a minute or so to consider their answer, and then ask for possible answers. Answers are provided on the next page.]
	[They should begin to see (visually) the process for the followed by the Minimum Green timer.] **Answer**: As shown in the figure, the Minimum Green timer begins timing at the start of the green indication. Its initial value is equal to the Minimum Green time. It continues timing until it reaches zero. The duration of the green indication is at least equal to the length of the Minimum Green time.
	**Ask**: What is the process followed by the Vehicle Extension timer from the beginning of the green indication, until the timer expires?
	**Answer**: The Vehicle Extension timer begins timing when the detection zone becomes unoccupied and there is no call on the active phase. If it reaches zero, the green indication may terminate. If it has not expired, the Vehicle Extension timer is reset when another call is received.
	**Ask**: What is the process followed by the Maximum Green timer from the beginning of the green indication, until the timer expires?
	**Answer**: The Maximum Green timer begins timing when there is a serviceable call on a conflicting phase. Once it begins to time, the timer continues until it reaches zero. When it reaches zero, the green indication is terminated.

Slide	Text
	**Ask**: What are the two conditions that separately cause the termination of the green indication?
	[This slide shows the phase termination processes as represented by the controller status screen for the two cases: gapping out and maxing out.] **Answer**: There are two conditions for termination of the green indication at an isolated actuated intersection: (1) the Minimum Green timer equals zero and the Vehicle Extension timer equals zero, or (2) the Maximum Green timer equals zero. • The picture on the left shows the ASC/3 controller status at t = 52.6, when phase 4 has just gapped out and the yellow interval has begun. This is the case on the left that you just observed in the movie. • The picture on the right shows the ASC/3 controller status at t = 71.4, when phase 4 has just maxed out and the yellow interval has begun. This is the case on the right side of the movie.
	[The slide shows a graphical representation of the process of gap out for case 1.] **Tell**: This chart shows the process of "gapping out," the first condition described on the previous slide. The green indication begins at t = 45.7 seconds; the Minimum Green timer also begins at this point. The Minimum Green timer expires after 5 seconds. The Vehicle Extension timer begins timing down at t = 50.1, when the detection zone is first unoccupied. When it reaches zero (at t = 52.6), the green indication ends (the phase "gaps out") and the yellow interval begins.
	[The slide shows a graphical representation of the process of max out for case 2.] **Tell**: This chart shows the process of "maxing out," the second case. The green indication begins at t = 51.4. The Minimum Green timer begins at this point and continues to time down until it reaches zero at t = 56.4. • The Vehicle Extension timer remains at its initial value (2.5 seconds) as long as a vehicle is in the detection zone (and a call remains active on phase 4). The timer begins to time down several times during this green indication but is reset to 2.5 when the next vehicle enters the detection zone. You can observe this process of

Slide	Text
	timing and resetting in the middle chart. • The Maximum Green timer also begins at the beginning of the green indication because there is an active call on phase 2 (a conflicting phase) at this point. The Maximum Green timer times down and the green indication terminates, even though the Vehicle Extension timer is still active.

Solutions

The solutions presented here include

- Critical thinking questions and answers
- Some example student answers
- Other student responses
- Other helpful hints

Critical Thinking Questions and Answers

1. Why does the phase terminate for each of the two cases that you observed?

- In the first case, the phase terminated because the Vehicle Extension timer expired ("gapped out"). In the second case, the phase terminated because the Maximum Green timer expired ("maxed out").

2. What is the process followed by the Minimum Green timer from the beginning of the green indication, until the timer expires?

- The Minimum Green timer begins timing at the start of the green indication. Its initial value is equal to the Minimum Green time. It continues timing until it reaches zero. The duration of the green indication is at least equal to the length of the Minimum Green time.

3. What is the process followed by the Vehicle Extension timer from the beginning of the green indication, until the timer expires?

- The Vehicle Extension timer begins timing when the detection zone becomes unoccupied and there is no call on the active phase. If it reaches zero, the green indication may terminate. If it has not expired, the Vehicle Extension timer is reset when another call is received.

4. What is the process followed by the Maximum Green timer from the beginning of the green indication, until the timer expires?

- The Maximum Green timer begins timing when there is a serviceable call on a conflicting phase. Once it begins to time, the timer continues until it reaches zero. When it reaches zero, the green indication is terminated.

5. What are the two conditions that separately cause the termination of the green indication?

- There are two conditions for termination of the green indication at an isolated actuated intersection: (1) the Minimum Green timer equals zero and the Vehicle Extension timer equals zero, or (2) the Maximum Green timer equals zero.

Example Student Answers

1. Why does the phase terminate for each of the two cases that you observe?

- Each of the cases terminated due to a gap out and a max out. The case on the left gapped out while the case on the left maxed out.
- Two conditions that separately cause the termination of the green indication and gap out and max out.

2. What is the process following by the minimum green timer from the beginning of the green indication until the timer expires?

- The process following the minimum green timer is that the timer gets reset by the passage timer if a vehicle is there and then expires if a large enough gap occurs if not then the maximum green timer will expire and terminate the green cycle.

3. What is the process followed by the vehicle extension timer from the beginning of the green indication, until the timer expires?

- It waits till the min green expires and starts to count down as cars leave the detection zone.

4. What is the process following by the maximum green timer?

- The process following the maximum green timer is the timer expires and the light will immediately turn yellow and red.

Other student responses

- We observed that due to the traffic demands the two different times gapped out and maxed out. We also observed that the minimum green time was 5 seconds, extension time was 2.5 seconds and the maximum green time was around 20 seconds.

Helpful Hints

- Explain the notation in the ASC/3, and focus them on parts of the screen to observe.
- Define C, T, Ring#, Phase#.
- What is the main difference between the two scenarios?

Using Activity #21: Exploring a Controller Emulator (Discovery)

Overview
In this activity, students will explore another view of the signal timing process by using a signal controller emulator build in Excel. The emulator is fairly simple, involving two one way streets, and pulse (not presence) detection. Students press buttons to simulate detector calls. The resulting timing processes allow them to visualize the three standard actuated timing processes.

Options for Use
This activity can be done either as homework or as part of class.

Preparing for the Activity
The best way to prepare for this activity is to explore the emulator yourself. Test how it works and observe the responses. It is not a difficult process but hopefully one that will engage the students with another view of controller operations.

Doing the Activity (Script)
No slides have been prepared for this activity since you can open the spreadsheet and demonstrate its operation directly. Invite the students to read the activity and open the spreadsheet emulator. Review the Critical Thinking Questions with them and discuss their answers once they have completed the activity.

Solutions
The solutions presented here include:
- Critical thinking questions and answers
- Example student answers to question 4
- Other student answers
- Helpful hints

Critical Thinking Questions and Answers
1. How and when do the phases terminate when no detector calls have been placed?
- The phases gap out immediately, but once the min green timer finishes counts down.
- Since there are no vehicle calls, the phase terminates because the minimum green timer expires.

2. When calls are placed continuously only on the NB approach, how and when does the northbound phase terminate?
- The phase does not end because the max green timer does not start to count down. This happens because no calls are placed on a conflicting movement (the WB detector).
- As long as calls are placed regularly on the NB approach (such that the passage timer continues to time), the phase will continue to run indefinitely.

3. When calls are placed continuously on both the NB and WB approaches, how and when does the northbound phase terminate?

- The phase ends due to a max out. The phase lasts for the max green timer, 10 seconds, because a conflicting call is placed immediately after the NB phase turns green.
- The NB phase continues to time, but only because there is an error in the logic of this simulator. You should note that the maximum green timer begins to time when the first WB call is placed. However, when the second call is placed, the maximum green timer stops (obviously a bug). If you only placed one call on the WB phase, the maximum green timer for the NB approach would expire and the phase would "max out".

4. How does pulse detection differ from presence detection and how does this difference affect the timing processes that you see in this controller emulator?

- In pulse detection, a call is only active when the call is initially made ("the pulse). This means the setting the passage time is a different task (to be discussed later in chapter 6) than for presence detection.

Example Student Answers to Question 4

- Pulse detection shows that there are vehicles continuously showing up and resets the passage timer continuously compared to the presence detector shows when a vehicle is actually waiting to be served but gaps out instead of maxing out.
- How do pulse detections differ from presence detection and how does this difference affect the timing processes that you see in this controller emulator? Presence: does not count down passage timer Pulse: resets timer every time a car goes through. [Note: this answer is not correct]
- Presence detection- extension timer starts to run down as soon as a vehicle leaves and the detection zone becomes unoccupied. It is reset when vehicle enters the detection zone.
- Pulse detection- pulse detection is instantaneous. The extension timer resets as soon as vehicle enters detection zone and activates detector.

Other student answers

- Without any detector calls the phases end by minimum green time due to no timer reset from the passage timer.
- When continuous calls on the north bound approach only the timer does not terminate due to no maximum green time counter.
- When continuously making calls to both north and west bound movements the maximum green timer counts down. Maximum green is only ten seconds long.
- Pulse detection shows that there are vehicles continuously showing up and resets the passage timer continuously compared to the presence detector shows when a vehicle is actually waiting to be served but gaps out instead of maxing out.

Helpful Hints

- Clarify "pulse" operation in spreadsheet.

Some students forget that maximum green timer won't start until a call is placed on the conflicting phase.

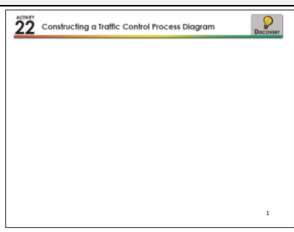
Using Activity #22: Constructing a Traffic Control Process Diagram (Discovery)

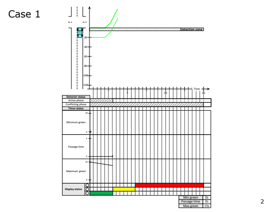
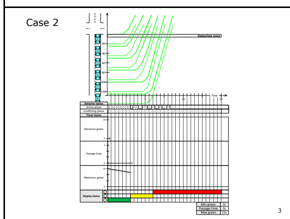
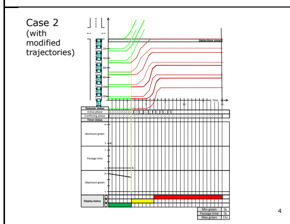
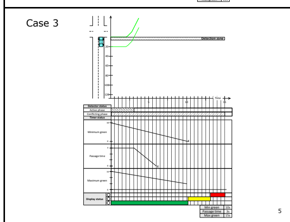
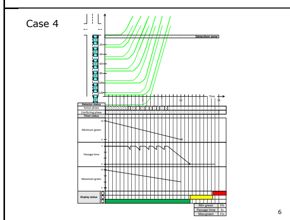
Overview
The purpose of this activity is for students to improve their understanding of the operation of an actuated traffic controller system by studying eight cases of signal timing setting and preparing a set of Traffic Control Process Diagrams for each case. Students have previously created Traffic Control Process Diagrams in Activity #20, and they should already be familiar with how the minimum green, maximum green, and vehicle extension timers operate. This activity should allow students to gain a deeper understanding of how the detector length in conjunction with the selected timing parameters can affect the performance of an intersection approach.

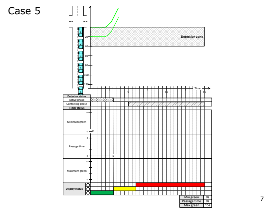
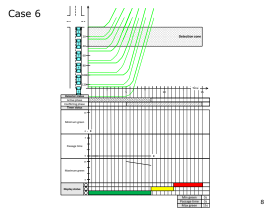
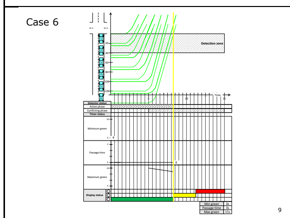
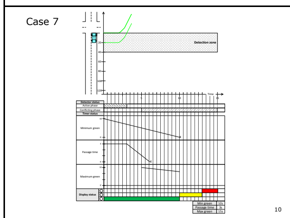
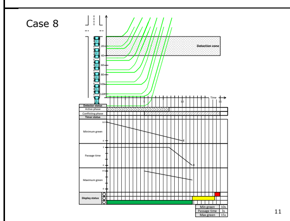
Options for Uses
This activity can be done either in class or as homework. Discussion of the results should be done during class.

Preparing for the Activity
The best way to prepare for this activity is to review the eight cases and the solutions for each. It is also helpful to review the solutions and some of the major points that can be deduced from the activity results.

Doing the Activity (Script)
[Slides: slides22.pptx]
You can use all or some of the following script (and slides) to conduct this activity.

Slide	Text
	Invite the students to read through the activity and review the eight cases shown in the diagrams. Complete the detector responses, timer responses, and signal display responses for each of the eight cases that follow. The conditions for each case are shown in the lower right of each figure. Assume Y = 3 and AR = 1. Prepare a summary of the unused green time and the percentage of vehicles served for each of the eight cases. Note that you may have to redraw the vehicle trajectories in response to changes in the vehicle displays. What questions do you still have on signal timing processes after completing this activity? • Make clear that vehicle trajectories are subject to change, based on timing and display.

Slide	Text
	Case 1. There are three steps, as shown in the figure above: First, the vehicle trajectory activates the presence detector. Second, detector calls generate response from the timers in the controller. Third, signal displays respond to signal timing logic. As long as a vehicle is in the detection zone, the call is active. The active status of the detector is shown above in hatched gray. When the vehicle leaves the zone, the call becomes inactive (and is shown in white). The minimum green timer begins to time down at the beginning of the green interval. Since the minimum green time is set to zero, it expires immediately. While the passage timer begins to time at the beginning of the green interval, it is continually reset as long as the vehicle call is active. When vehicle 1 leaves the detection zone, it begins to time down. Since the passage time is set to zero, it expires immediately and the green interval terminates at that point.
	Case 2. While there are six vehicles waiting in the queue, only the first vehicle is served in this timing configuration. As in case 1, when vehicle 1 is in the detection zone, the call is active. When vehicle 1 leaves the zone, the call is dropped. Despite the arrival of the second vehicle soon after the first vehicle, the green interval terminates when the first vehicle leaves the zone, just as in case 1.
	Case 2 (continued): Note also that the trajectories beginning with vehicle 3 are modified because the yellow indication is displayed before the queue has been served. The yellow interval is shown by the vertical yellow line.
	Case 3. While the passage timer expires when vehicle 1 exits from the detection zone, the minimum green timer continues to time. The minimum green timer expires ten seconds after the beginning of the green interval. At this point, since the passage timer has also expired, the green interval ends.
	Case 4. The minimum green timer begins to time at the beginning of the green interval and expires after ten seconds. The passage timer alternates between resetting and timing as the calls go from active to inactive. Also, since a call on a conflicting phase is active, the maximum green timer begins to time at the beginning of the green interval. The last vehicle exits the detection zone at about t = 7, so the passage timer expires three seconds after that. At this point, the phase terminates.

Slide	Text
	Case 5. In this case, the detection zone is 40 feet in length. However, since there is only one vehicle in the queue, the reaction of the timing processes to the detector status (as well as the display status to the timing processes) remains unchanged, with the phase terminating immediately after the first vehicle is no longer detected.
	Case 6. The effect of the detection zone length is shown in this case. As compared with case 2, the green interval is extended, even though the passage timer is set to zero, since the detection zone remains occupied until the sixth vehicle leaves the zone. At this point, the passage timer begins to time down and immediately reaches zero (the setting for the passage time).
	Case 6 (continued). This slide shows the time that the last vehicle leaves the zone, with the immediate expiration of the passage timer. At this point, since the minimum green timer has already expired, the phase terminates.
	Case 7. The minimum green timer expires ten seconds after the beginning of the green interval. There is more unused green time in this case since the vehicle departed, and the call was dropped several seconds earlier than the green interval ended.
	Case 8. The minimum green timer expires ten seconds after the beginning of green but the green interval continues as the passage timer is still active. There is also a call on the conflicting phase (that is initiated at the beginning of the green interval), and the maximum green timer begins to time. The phase gaps out when the passage timer expires.
	Following is a summary of the phase timing processes superimposed with the vehicles arriving at the stop bar. The trade-offs in using a short (6 foot) vs longer (40 foot) detection zone. The short zone requires a non-zero passage time and minimum green time, while the longer zone doesn't require non-zero values for these parameters. For example, a "best" design for the 40 foot zone would have a value between 0 and 3 seconds for the passage time, but would operate efficiently with a 0 minimum green time. A longer zone (such as 60 feet) could probably accommodate a zero passage time. Some other notes are useful to review and discuss with students: • Cases 1 and 2: For low volumes (here, a queue of 1), short detection zone (6 feet), and zero values for minimum green and passage time, the is efficiently served as the green time terminates

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<tr><td></td><td>
when the vehicle enters the intersection. But when the demand is higher (here a queue of six vehicles), a combination of the short detection zone and zero passage time the phase ends before the queue is served.

Cases 3 and 4: The minimum green time is 10 seconds and the passage time is 3 seconds, so both the short and long queues are served. But with the short queues and longer minimum green time, nearly 7 seconds of unused green time results, time that could be used to serve other phases.
The longer loop (40 feet) in cases 5 and 6, even with minimum green of zero and passage time of zero, both the short and long queues are served, and there is no unused green time. So a longer loop allows the phase to extend as long as demand or queue requires service.
Cases 7 and 8 also uses longer loops, but with non-zero minimum green and passage times. While both demand levels are served, the longer minimum green time results in unused green time for the lower volume condition.

So what can we learn (in general):

The detection zone length should be long enough to the parts of two vehicles can occupy the zone at the same time.
The minimum green time should be long enough to serve the initial portion of the departing green, but not much longer. [Note however that it is standard in practice for the minimum green time to meet driver expectancy, which means that in most cases minimum green times are set to at least 5 seconds, regardless of zone length]
The passage time and detection zone length must be considered together which we will see in chapter 6.

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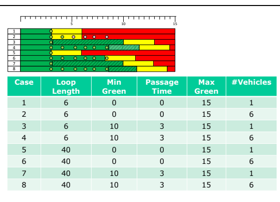
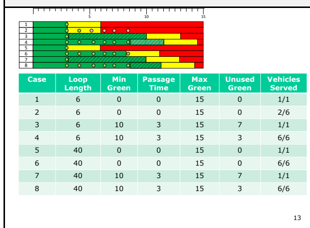
<tr><td>


</td><td>
The top figure shows the green, yellow, and red displays for each of the eight cases and when each of the vehicles are served (or not). The circles in green indicate that a vehicle is served, while the red circles indicate that the vehicle does not make it through the intersection before the display changes to red.

The table below summarizes the characteristics for each of the eight cases.
</td></tr>
</table>

<table>
<tr><th>Slide</th><th>Text</th></tr>
<tr><td>
</td><td>The top figure below shows graphically the unused green time that results for cases 3, 4, 7, and 8.

The table below shows a summary of efficiency (as measured by unused green) and quality (as measured by the proportion of vehicles in the queue that are served).</td></tr>
</table>

Solution

Critical Thinking Questions and Answers

1. What questions do you have on the signal timing processes after completing this activity?

2. Can unused green time (the time after the last vehicle passes through the intersection and the onset of yellow) be effectively used? Describe some of the issues that you considered in your answer.

- If it is long enough.

3. If you have to redraw any of the vehicle trajectories, how does this relate to the four interrelated steps in the traffic control process diagram that is first described in chapter 1?

- This relates to how the signal display affects users.

Other Notes

Helpful Hints

1. Note short vs long detectors.
2. Note issues with zero minimum green and passage time.
3. Note when maximum green starts (only when conflicting call is received)
4. Start with drawing when calls are active and not active.
5. Identify when zone is occupied or note (call is active or dropped)
6. Identify when phase terminates and how.
7. Get students to think about interactivity of the components.

Reflections

Some observations of students doing this activity that they didn't get:

- The need to go from time space diagram to detector status for the activity phase.
- That the three timing processes operated independently
- The specific path followed by each timing process (when each began, how it timed, and when it could be reset).
- The logic for phase termination process (based on timing process).
- The activity actually took 50 minutes for most of them to complete; I took time to explain about the steps:
- Detector status in response to the vehicle trajectories
- Timing processes in response to both detector states (active and conflicting)
- Determine the phase termination process based on the timing processes

- Draw displays in response to the timing process states
- [possibly modify this to include changing vehicle trajectories in response to the displays]

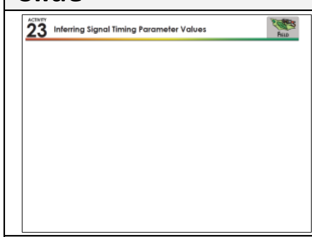
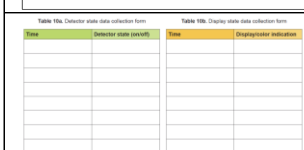
Using Activity #23: Inferring Signal Timing Parameter Values (Field)

Overview
In this activity, students will test their knowledge about signal timing parameters by going out into the field and estimating timing parameters. They will build on what they did in Activity #15 when they synthesized a ring barrier diagram based on their field operations. They will observe the durations of the green, yellow, and red displays and synthesize the timing parameters (minimum green time, passage time, and maximum green time) based on these observations.

Options for Use
This activity is done in the field, though discussion of the results should occur during class.

Preparing for the Activity
Prepare for the activity by reviewing the instructions and some of the issues that students will confront during their field work and subsequent analysis.

Doing the Activity (Script)
[Slides: slides23.pptx]
The following script can be used along with the slides for the activity. The script and slides can be modified based on your needs and what you decide to emphasize for the activity.

Slide	Text
	Invite the students to read through the activity.
	Tips for field activity • Observe on minor streets. This is done because it is assumed that the major approach has a call placed immediately after the major street phase ends. • Document how many vehicles were served this helps to determine the minimum green time. If only one vehicle is served, the minimum green time will be the primary timing factor during that cycle. • If you can't determine detector location; find a physical marker in/near the road (road crack, building, etc) approximately 20 ft. from the stop bar and count that area as the detector.

Solutions
[See example data files for Moscow intersections in solutions23.xlsx.]

The following example solution is for the intersection of Line Street and SH8. The table below shows example data collected in the field. The color coding was used to explain how the values were calculated. [Note: the time shown is the elapsed time for each event]

Cycle 1		Cycle 2		Cycle 3		Cycle 4		Cycle 5	
Event:	Time:	Event:	Time:	Event:	Time:	Event:	Time:	Event:	Time:
R	0	R	0	R	0	R	0	R	0
O	0.8	O	1.2	O	0.4	O	2.8	O	2.8
G	53.6	G	88.5	G	39.5	G	74.9	G	74.9
F	3	F	2.7	F	2.4	F	2.1	F	2.1
Y	3.1	O	2.3	Y	3.1	O	0.7	O	0.7
R	2.9	F	1.3	R	2.9	F	2	F	3.8
		Y	2.2			Y	3.5	O	12.3
		R	3.1			R	2.9	F	1.5
								O	4.5
								F	2
								Y	3.1
								R	2.9

Key	
G	Signal turns green
Y	Signal turns yellow
R	Signal turns red
O	Detector turns on
F	Detector turns off

The estimated timing parameters are shown in the table below.

Minimum Green	5.8	sec
Passage Time	2.9	sec
Max Green	30	sec
Yellow Time	3.0	sec

- Minimum green was taken as the sum of F and Y for cycles 1 and 3 and then averaging them. Cycles 1 and 3 were used because only 1 vehicle traveled through during the cycle.
- The passage time was estimated by averaging the Y for cycles 2 and 4.
- The maximum green was taken as the maximum of the sum of F to Y for each cycle. The maximum green occurred during cycle 2. It is unlikely that the maximum green time is 8.5 seconds this was the longest green time seen in the field.
- The yellow time was estimated as the average of R for each cycle.

Other Notes

Helpful Hints for Instructor

- Get field detector locations to help them locate detection zones.

- What should students do when detection zone is not clear when video detection is used? Should include instructions for this.
- How to “sleuth” the values for the different timing parameters:
  - Minimum green can be observed on a low volume approach.
  - Vehicle extension time can be observed both in looking at gaps between vehicles (for low end) and time from last vehicle until yellow (for high end).
  - The maximum green time could be observed on the higher volume approach, where the queue didn’t clear before the end of green.
- Still issue of how to present the data: a series of TCPD don’t make sense as much as a good data summary. Should be clearer on detector location and how to collect these data to estimate passage time. Also, it would be good to have ITD signal timing data so that they can compare their results with what actually exists in the field. Students noted that the passage time estimation was the most difficult.
- Note interaction with compatible phase and how the timing on this phase affects the timing of the subject phase.
- Should this be done for intersection or approach?
- Where to site the detection location?

Notes for this activity to be considered in discussion:

- Should have done intersection or approach? This needs to be clarified, probably focus on one approach only; this would make it more straightforward.
- Be clearer on detection analysis-where are they located?
- This discussion is good to have them refresh their memory about what they did and what was important.
- Passage time is hard to do, especially need definition of detection zone length.
- Note interaction with compatible phase and implications for their data.

Using Activity #24: Signal Timing Parameters (In Practice)

Overview
This activity provides the student with the opportunity to connect what they have learned in the previous activities with practice as defined in the Traffic Signal Timing Manual.

Options for Use
This activity is usually done as homework, but the discussion should occur during class.

Preparing for the Activity
Review the relevant section of the Traffic Signal Timing Manual.

Doing the Activity (Script)
You can lead a discussion on the reading from the Traffic Signal Timing Manual and how it relates to what the students have learned in this chapter, including their field work.

Solution
Critical Thinking Question and Answer
1. Describe how the timing processes that you observed in the field (Activity #23) compare with their descriptions in the Traffic Signal Timing Manual.