Background & Motivation
Many people know the thrill of “Getting all green lights” when driving. While sometimes it may be due to pure coincidence, we Traffic Signal Technicians and Traffic Engineers know that it is because a traffic signal coordination program is running properly. It does take time and effort to create, implement and maintain a good signal coordination plan. However, the benefits cannot be understated; less wasted fuel, cleaner air, reduced accidents at intersections, and perhaps the most important of all, people get where they are going quicker and have more time.

For a long while I have seen a need for a useful article written for the field technician that explains traffic signal coordination. There is so much involved with coordinating traffic signals and some technicians have difficulty understanding the concepts. Though this article is written based on NEMA TS-1 and TS-2 traffic signal controllers, many of these concepts can be translated into 170, 2070 and ATC environments.

Traffic Signal Coordination can best be defined as synchronizing two or more nearby signals on a certain street so that vehicles can progress along the street with minimal stops and delays. Engineers will develop a signal coordination plan based on a number of factors, mainly speed, volume and intersection spacing. A “Time-Space” diagram is developed to visually show how a coordinated signal system would work and show how vehicles would progress through intersections through “green-bands. The signals, after the coordination plan is implemented, need to be kept “in sync”.

To keep signals “in-sync”, Many coordinated signals still use hardwire sync pulses, coax, and of course the most popular in my neck of the woods Time-Based Coordination (TBC), where each controller’s internal clock keeps the signal in sync. I believe that in many areas the “status quo” coordination methods are adequate, though they do not have the shiny new technological “wow” of the closed loop and adaptive systems.
Coordinating Traffic Signals for Field Technicians . . . Continued from page 22
that get all of the attention these days. If these legacy systems are properly maintained, and timings periodically reassessed, the equipment can continue to serve for years to come.

Cycles, Splits and Offsets
Traffic Engineers design coordination plans to use common cycle lengths to ensure vehicle progression along a certain street or highway. This street is sometimes referred to as the “major street”, “arterial” or “corridor”. Cycle lengths used in traffic signal coordination generally range from 60 to 200 seconds. Longer cycle lengths are generally able to move more traffic, because there is less lost time from startup and clearance times. The downside to using long cycle lengths is that side street traffic is required to wait longer and this can generate complaints from citizens. Though cycle lengths need to be kept consistent, occasionally you may find an adjacent minor intersection running a “half cycle”. An example would be an arterial cycle length of 120 second with the minor intersection timing a 60 second cycle.

A split refers to the amount of time in a cycle length given to a particular phase. This time would include the green, yellow and red clearance time of a particular phase. The sum of all of the splits, in seconds, should equal the cycle length.

Splits are usually expressed in seconds; however, many older solid state controllers still in use require the use of percentages. The use of percentages stems from electromechanical controllers (still in wide use in some cities) where a dial is divided up into 100 equal parts and a changeable cycle length gear was on the back. In this environment, percentages are the primary measure of time. Some of the current controllers on the market allow the user to select between seconds and percentages. If you have a mix of electromechanical and solid state controllers on a common arterial, percentages should be used if possible to minimize any possible confusion.

Here are the two formulas for converting splits between each unit of measure:
• Converting split % into seconds: multiply the percentage by the cycle length. Example - a 40% split on a 120 second cycle would be .40 x 120 = 48
• Converting seconds into split %: divide the split time in seconds by the cycle length. For example, a 42 second split in a 75 second cycle would be 42 / 75 = .56 or 56%

An offset is the amount of time difference between the local cycle and the master cycle. If a particular intersection has an offset of 5 seconds, this means that the local intersection will time five seconds behind the master intersection with an offset of zero. The intersection with a 5 second offset will turn yellow 5 seconds after the master intersection. It is also interesting to note that some older solid state controllers require the user to have the offset in seconds while the splits are programmed in percentages.

These photos show an offset relationship between two coordinated traffic signals

“This signal with zero offset with an end green reference has just been forced-off to yellow”

“Five seconds later, the downstream signal with a 5-second offset turns yellow”

An offset must be referenced to a particular point in the cycle. As a field technician who maintains the equipment, my personal preference is an offset reference to the end of the coordinated phase. This allows the tech easy verification that traffic signals along a roadway are “in sync”. With a beginning of green (beginning of both coordinated phase green), “TS2 first green” (the leading left turn phase) offset references, different coordinated phase green lengths at each intersection have to be taken into account.

Continued on page 26
Most controllers allow the user to select an offset reference point. However, at some time, the Traffic Signal Technician may be required to adjust an offset value to match the existing controller’s reference point that cannot be changed. If you need to change the offset reference from beginning to end of green, add the coordinated phase green time. If the offset reference change is from the end to the beginning, deduct the coordinated phase green time. It is very important to note here that we are adding or subtracting the green time only, not the entire split, so subtract the yellow and red clearance times from the split.

The Coordinated phase
In order for coordination to operate, a phase must be designated as the coordinated phase. The coordinated phase is the phase of the street to be coordinated. If your controller is running a NEMA dual ring configuration you must have a coordinated phase from each ring (Typically phase 2 & phase 6). In most cases, the phasing will be kept constant along the corridor; for example, phase 2 always being the eastbound approach and phase 6 always the westbound.

Even if detection is present for the coordinated phase, it will always run fixed-time during coordination. This is to guarantee that adequate progression will always be provided for the arterial. The exceptions would be if you have a controller with a manufacturer specific adaptive capability, or a centralized system that can override local controller functions.

Use of Inhibit Max
Oftentimes during coordination, the phase splits will exceed the Maximum timings that are used during free operation. The controller must be programmed so that the free off peak maximum times will not terminate phases. This can be accomplished two ways. The most popular is to program “Inhibit Max” operation during coordination, which basically tells the controller not to terminate any phase by its max time. The second method is to use an alternate maximum time or second timing plan specifically during coordination. The maximum times used will be set to a time longer than the largest split used during coordination.

Fine Tuning Coordination
Fixed vs. Floating force offs & Permissives

With an intersection that is traffic actuated, the coordinated phase will operate fixed-time; however, other phases may gap out and not use their entire split time. Where the extra time goes is decided by the use of either “Fixed” or “Floating” force-offs. The most common method is to use “floating” force-offs where all of the extra time is always given to the coordinated phase. This is usually desirable, as the coordinated phases tend to have the most volume.

The use of “Fixed” force offs will let the next phase in the sequence use the extra time. For example side street left turn phase 3 gaps out, then phase 4 can get all the time that phase 3 did not use. This choice would most likely be used where two major arterials meet, and all phases could use any extra time they can get. The downside to using “fixed” force offs is that should a detector break for a phase that is later in the sequence, that phase can eat up all of the extra time without any demand.

“The use of Fixed force-offs can be beneficial at a major intersection such as this one”

Yield & Permissives
At some point within the cycle, the “hold” on the coordinated phase is lifted for it to serve non coordinated phases. This point is often known as the “Yield point”. Anytime thereafter is known as the “Permissive Period”.

All of the modern solid-state controllers provide the user with the ability to control how the intersection serves the actuated side street phases. The default and norm in my neck of the woods is automatic permissives. This is where the controller automatically calculates a permissive period for each phase based on minimum and maximum phase service times. Each permissive period is in chronological order and will mirror the ring sequence for that particular coordination plan.

The technician can choose between the use of “single” versus “multiple” permissive operation. “Multiple” permissives is the most commonly used and is similar in theory to the way automatic permissives operate. With “single” permissive operation, when the controller reaches its force off / yield point, it can serve the first phase that has demand. If phases 3 & 7 have no calls, then phases 4 & 8 can get served right away.

Continued on page 28
Manually setting permissives is where the user can control how much of a “window” the non-coordinated phases can get. If a heavily traveled arterial should always get as much green time as possible, this feature could be useful. A very small permissive can be manually set, so that any vehicles that pull up on the side street after the end of the coordinated phase yield point will have to wait another cycle. The downside to this operation is that a vehicle that pulls up just after the permissive period will have to wait an entire cycle length, and this can generate complaints from citizens.

Correction methods
A “Correction” method (also known as “Offset Seek” or “Transition”) is used when for whatever reason the coordinator has gone “out of sync”. Situations would include transitioning from one coordination pattern to the next, oversized pedestrian timings, and preemption.

The selection of correction methods can vary by controller, but generally include the following; Smooth/Shortway, Add Only, Subtract Only, Dwell and Max Dwell. In most cases the “Smooth/Shortway” selection is used. It allows the coordinator to get back into step by either shortening or lengthening phases, which ever is quicker. “Add-Only” would in many cases take longer to get the signal back in step, but phase splits would never be short timed. “Dwell” will have the signal rest in green for the coordinated phase until the correct offset is reached, which would provide the quickest transition of all options. This might be used if you have a severely congested arterial, and it is desired to always give all possible green time to the arterial. The major downside to “Dwell” is that all other phases may have to wait for a long time. Some controllers offer the option of setting a Max Dwell time for the coordinated phase. This correction would operate similar to “Dwell”, except that when the “Max Dwell” time was reached, the coordinated phase would be forced off and side street phases served, and this operation repeated until the correct offset was reached. If the Max Dwell time is properly set, it should only take one or two cycles to reach the new offset.

“This illustration shows the effects of different offset corrections on a coordinated intersection. (FHWA Signal Timing Manual)”
Problems that arise with coordination

Making field adjustments to a coordination plan can be as simple as completing the first level of “Angry Birds” or an arduous journey that can take multiple trips and perhaps some yelling from your boss.

While many coordination plans may look good on paper, getting them to operate in the field can be another story. Most modern controllers contain inherent failsafe logic that, when a coordination plan does not meet certain criteria, will cause the signal to run “free”. Some NEMA controllers will show you a diagnosis and tell you the exact nature of problem, while others will leave you to figure it out for yourself.

The sum of phase allocations or splits in at least one ring should equal the cycle length. Some controllers will tabulate the cycle length on the same screen as you enter the phase splits. Others have the cycle length entered on a separate screen and will flag a coordination error if your splits do not add up right.

Minimum phase timing violations will occur if the controller does not think that it can serve a phase minimum green with the allocated split time. If a phase has a 5 second minimum green and 4 and 2 second yellow and red clearances then this phase must have a split of at least 11 or 12 seconds programmed. (Controllers require minimum phase timing plus one or two seconds). Anything less would cause the controller to revert to “free” operation.

Oversized pedestrian timings will also cause an interesting hash of problems. A seldom used pedestrian movement that is concurrent with a minor vehicle phase may have a time that exceeds the phase split. For example, phase 8 may have a programmed split time of 18 seconds but have an actuated pedestrian crossing that uses a total of 35 seconds. How a solid state controller handles a variance such as this will vary by manufacturer and their software revision. The most common method among controllers is to go into a “correction” mode as if preemption or other type of interruption occurred. Other controllers will just steal all the time from the next phase in the sequence that would result in that phase timing its minimum time then being “forced off” right away.

In recent years, many agencies have installed “GPS Clocks” to mitigate the issue of local controller clocks drifting and loosing their time in a TBC environment, or even as a back-up if the interconnect fails. This device works by syncing the controller clock to satellite time at a certain point each day, usually in the early AM. Some controller models offer a selectable point within the day. It is wise to choose a common time for all controllers along the arterial.

Preventive Maintenance of Signal Coordination

In writing about preventive maintenance of coordinated signals, most of what I am about to talk about here would apply to systems where there is no central monitoring, or the field technician does not have access to the central system.

The first thing that any technician will want to observe is whether coordination is running at all. Many things can cause a signal to go to free operation such as all those mentioned previously, but also including a clumsy tech bumping the “Coord/Free” toggle switch inside the door during the last call out! If you are only
Coordinating Traffic Signals for Field Technicians . . . Continued from page 30

visiting the signal once and it has multiple coordination plans throughout the day and week, it may be prudent to manually activate each plan to check its operation. Signal controllers have the capability to manually activate each cycle/split/offset. Verify that each phase is getting its allotted time. If traffic is not very heavy and phases “gap out”, place the phases on “max recall” temporarily to simulate peak demand. While testing pedestrian push buttons, take note of the effect of any oversized pedestrian timings during the phases that follows.

Check the following against the coordination and/or signal plan; cycle length, the offset, offset reference, time of day operation of each different coordination plan. It is also important to verify that the adjacent signals are on the same cycle lengths at the same time, as this is required to maintain progression of vehicles.

If the intersection is coordinated by means of time based coordination (TBC), it is important to synchronize the time clock to a common source. Over the course of time, the internal clocks in the controllers can drift slightly for a number of reasons. With traffic signal coordination, seconds really do count. An “atomic clock” would be best for synchronizing controller time clocks for TBC and are widely available. Many of us also use cell phone clocks to set the time-of-day, however, it is not the most accurate source.

If a signal is interconnected with others in any way, you will also want to evaluate that during maintenance as well. The modern solid state controllers have status display screens that show communications with a master and also logging features that show communications and coordination faults. This enables the tech to find out problems that may be occurring on an intermittent or time of day basis. The voltage on a hardwire interconnect system should be checked against known values. Abnormally low voltage could be indicative of problems with the cable or splice points.

Citizens may approach you while performing preventive maintenance of a coordinated signal. Traffic Signal Technicians are the most visible personnel in the traffic signal profession and do receive colorful complaints from the general public, sometimes with a string of profanity that would make Andrew Dice Clay cringe. While it can be tempting for the tech to “write-off” any such complaints, technicians need to be professional and input from the public should be taken into consideration. This technician has found that after some investigation, surprisingly enough, real problems have been found!

Conclusion
There is so much more to talk about in regards to traffic signal coordination I have only scratched the surface on this fascinating topic. I hope that technicians and engineers will discuss technical issues such as this at meetings and on the online IMSA forum, with a goal to provide improved traffic signal operations. The benefits of well coordinated signals are something that we can provide to our family, friends and neighbors who drive through the signals we maintain on a daily basis.

Disclaimer:
I do not endorse any specific controller or manufacturer. Every effort has been made to verify that the factual information in this article is true and correct. This article is not meant to replace hands-on training, experience or continuing education. It is always recommended to follow your organization’s procedures for making any changes and adjustments.

Biography
Gregory Bremser is an IMSA Level II Traffic Signal Field Technician for Upper Darby, which is Pennsylvania’s largest Township, bordering Philadelphia, PA. He has been a moderator and active member of the IMSA New Jersey Section. He can be reached at gdbremser@yahoo.com

References
Econolite, ASC 3 Advanced System Controllers Programming Manual, Rev. 09 pp. 8-1 to 8-32
Naztec, Inc., Naztec Training Manual for NTCIP Based TS2/2070 Controllers, April 2008, pp.6-55 to 6-74