SIEMENS

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ST950 LRT Handbook

667/HB/46000/002

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1 INTRODUCTION

1.1 OVERVIEW

This handbook details the configuration and operation of the LRT Mode.

The handbook currently covers the ST950 Controller platform.

1.2 CONTACT US

If you have any comments on this handbook, or need any further information, you can contact us at trafficwebmaster.stc@siemens.com.

1.3 RELATED DOCUMENTS

The following documents are referred to in the text of this handbook and may be useful for reference.

a) 667/HH/46000/000 - ST950 Handset Command Handbook

b) 667/HB/46000/001 - ST950 Facilities Handbook

c) 667/HB/30000/000 - Helios General Handbook

1.4 ABBREVIATIONS

CLF	Cableless Linking Facility
DFM	Detector Fault Monitoring
IC4	Intersection Configuration tool
LRT	Light Rail Transit
ROW	Right Of Way
UTC	Urban Traffic Control
VA	Vehicle Actuated

2 LRT MODE

2.1 OVERVIEW

Traffic Controllers need to be specially configured to control LRT vehicles, typically trams. Siemens Controllers prior to ST950 are configured to control trams using the Bus Priority mode, with a large amount of Special Conditioning being required to modify and enhance Bus Priority mode to implement the requirements of LRT systems.

On ST950, LRT Mode can be configured to control trams without recourse to other modes or Special Conditioning, unless required by particular site considerations.

An example of the layout of an Intersection with LRT Signals is shown below and a typical sequence of events is shown in Figure 2-2.

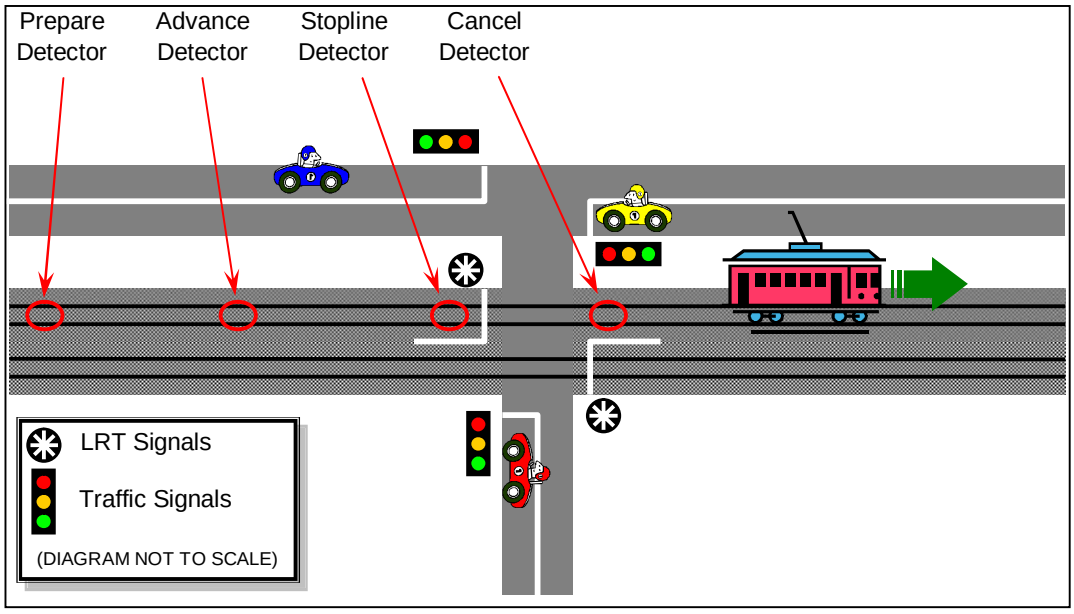


Figure 2-1 - Example LRT / Traffic Intersection

2.2 LRT UNITS AND LRT PHASES

Up to sixteen LRT facilities called ‘units’ may be managed. Usually, each tram route through the intersection is controlled by one LRT unit.

Each LRT Signal is controlled by one LRT Phase. Section 2.11 contains more information on the LRT Phase.

Each LRT unit controls one phase, which may be a real LRT Phase or a dummy phase. Two or more LRT units can be assigned to the same phase, e.g. where two routes converge just before the intersection and both are controlled by the same LRT signal.

2.3 LRT EVENTS

For each LRT unit, the following events may be configured, and are expected to occur in sequence.

- **Prepare** – The tram is approaching the intersection.
  Typically stage movements are prevented so that the intersection is ready to react to the 'Advance' Event.
- **Advance** – The tram is near the intersection.
  Typically the LRT phase is requested and the controller begins to move to a stage to give the tram phase right of way.
- **Stopline Presence** – The tram is at the stop-line.
  If the LRT phase is not at right of way then it is requested.
- **Stopline Cleared** – The tram has passed the stop-line.
  If the LRT phase is at right of way, then it is terminated since the tram has now passed the LRT Signal. Intergreen Delays extends the intergreen to any conflicting phases in the next stage.
- **Cancel** – The tram has passed through the intersection.
  The Intergreen Delays cease and the controller resumes normal operation.

An LRT Event can be triggered by an input changing state; the polarity of the change is configured as well as the input name.

By default, the normal detector scanning algorithm is used to detect short activations of the input. Alternatively, a de-bounce algorithm can be enabled (similar to that used on UTC control bits) if it is required that short transients on an input are not treated as valid events.

An event can also be triggered from Special Conditioning so that logical combinations of inputs can be specified where required. In the IC4 configuration, enter a scratch bit name as the input for the event.

Each LRT Event triggers its Actions after a configurable Event Delay (which can be zero). Event Delays may need to be specified if the physical detector had to be located earlier on the path of the tram because of issues at the ideal location. The same change of state of one input can also be configured to trigger two different events, separated by the configurable delay period.

An Action may trigger an effect which lasts for a period of time, known as an influence. It is possible to configure what influences are triggered by the Actions for the Prepare and Advance Events. The influences triggered by Actions for other Events are fixed, such as the Stopline Presence Action always inserts an LRT Request influence for a configured period.

The Actions of one LRT Event normally cancel the influences of the previous LRT Event on the same LRT Unit, e.g. the Advance Actions cancel the Prepare influences.

The following sections cover Event Delays and the Actions for each LRT Event in more details, and the diagram overleaf shows the typical sequence of events.

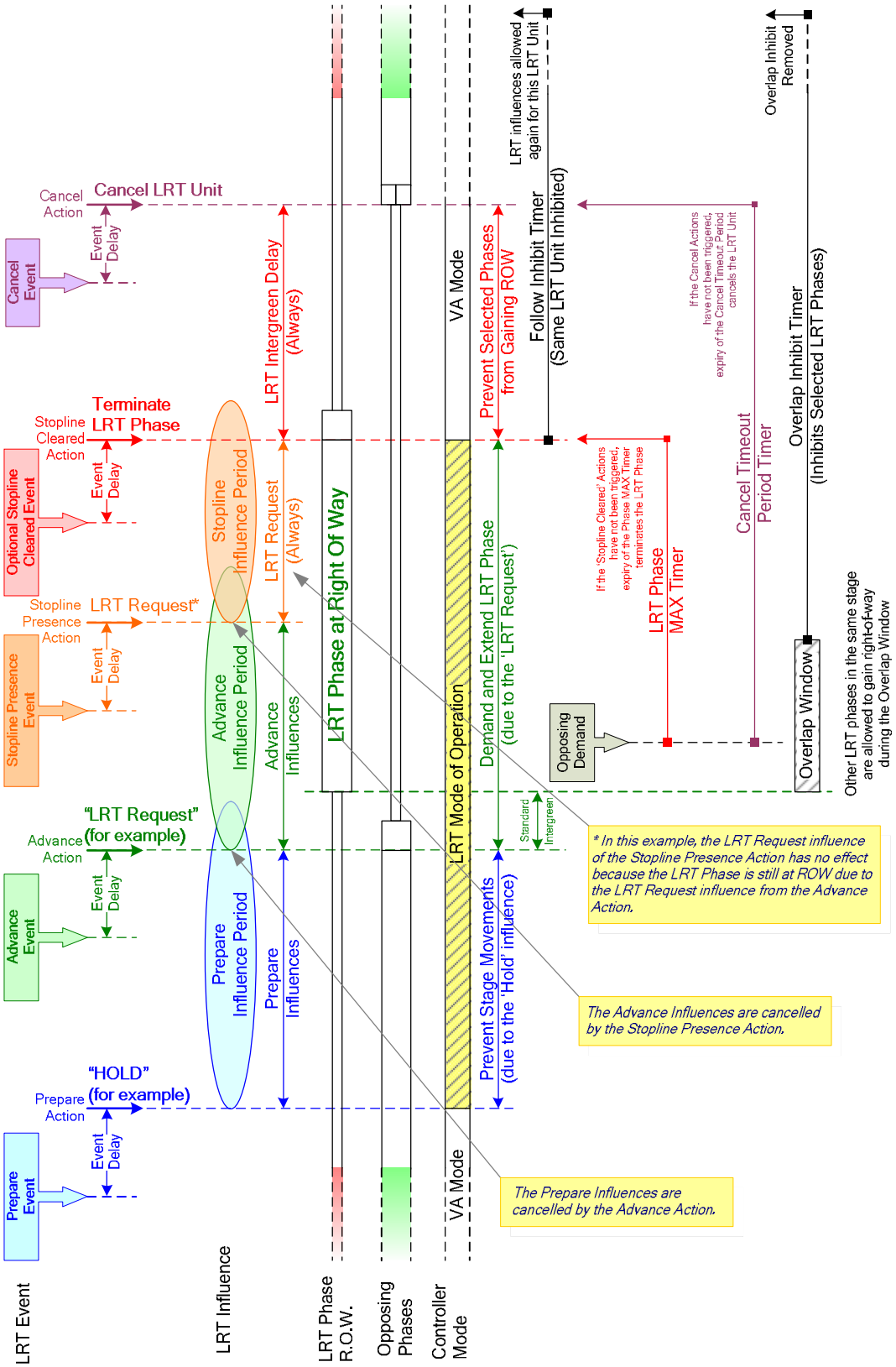


Figure 2-2 - Typical LRT Sequence

2.4 EVENT DELAYS

An Event Delay can be specified between the Event (the input change of state) and the Actions being triggered.

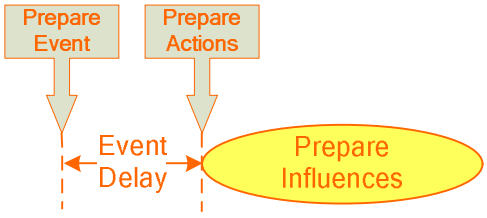


Figure 2-3 - Event Delay Example

Event Delays are configurable for each Maximum Green Time Set, allowing for differing conditions during the day for example. More information on the Time Sets is in section 2.18.

The configured delay periods can be viewed and modified on the LRT General Timing Web Pages (Figure 2-4).

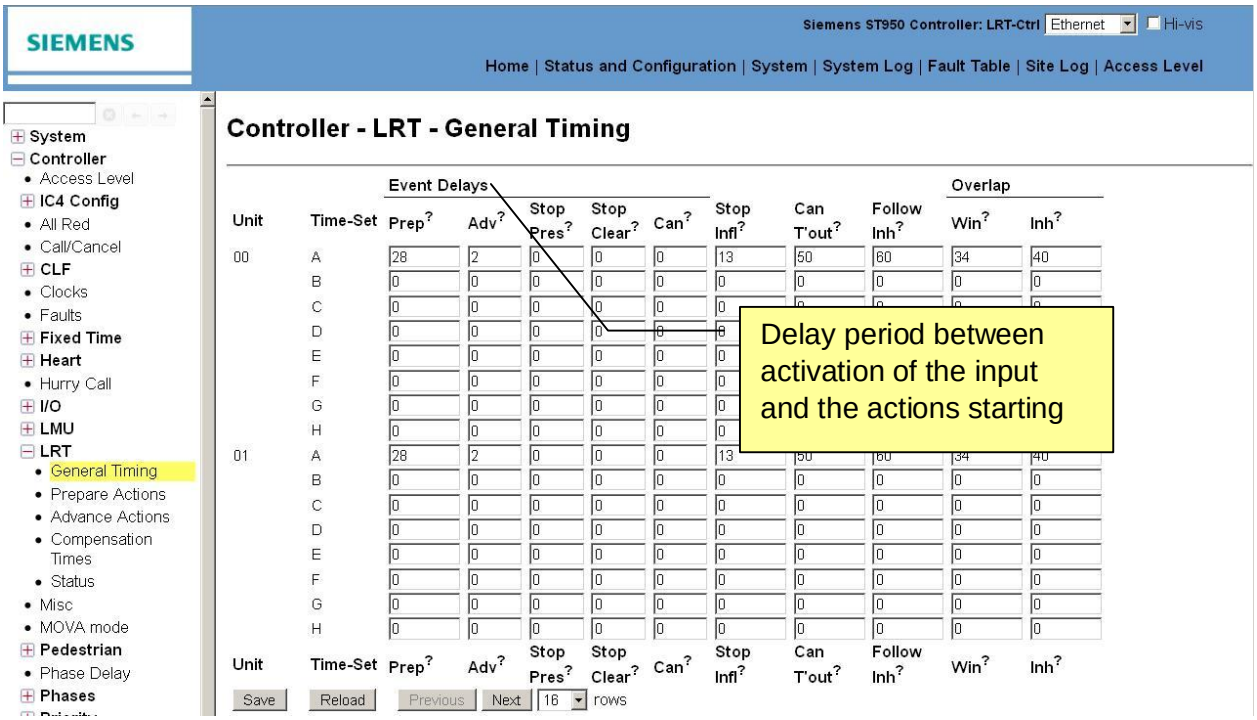


Figure 2-4 - General Timing Data

The other time periods on the General Timing web page are described later:

- Stopline Influence Period – section 2.6
- Cancel Timeout Period – section 2.9
- Overlap Window Period – section 2.12
- Overlap Inhibit Period – section 2.12
- Following Inhibit Period – section 2.13

2.5 LRT PREPARE AND ADVANCE ACTIONS

For the Prepare and Advance Actions up to six sequentially timed steps can be defined.

For each step the following need to be configured: a duration, an influence function and optionally a phase. These influences affect the operation of the controller for the duration of the step.

- Each step runs for a configurable **duration**, and then next step begins. This continues until all the configured steps have executed, or more typically the influences of this LRT Event are cancelled when the Actions for the next LRT Event in the sequence are triggered by the tram moving through the intersection.
- For each step one of the **influence functions** must be selected by the configuration. These functions influence the operation of the controller for the duration of the step. The available influence functions range from simply inserting a VA demand for the specified phase through to an 'LRT Request' influence that requests LRT mode so the LRT Phase gains right of way as soon as possible.
- For some influence functions a **phase** must also be specified in the configuration. With other influence functions, any specified phase is ignored because the function always uses the LRT Phase associated with the LRT Unit.

These configuration settings can be accessed on the Prepare and Advance Web Pages, Figure 2-5.

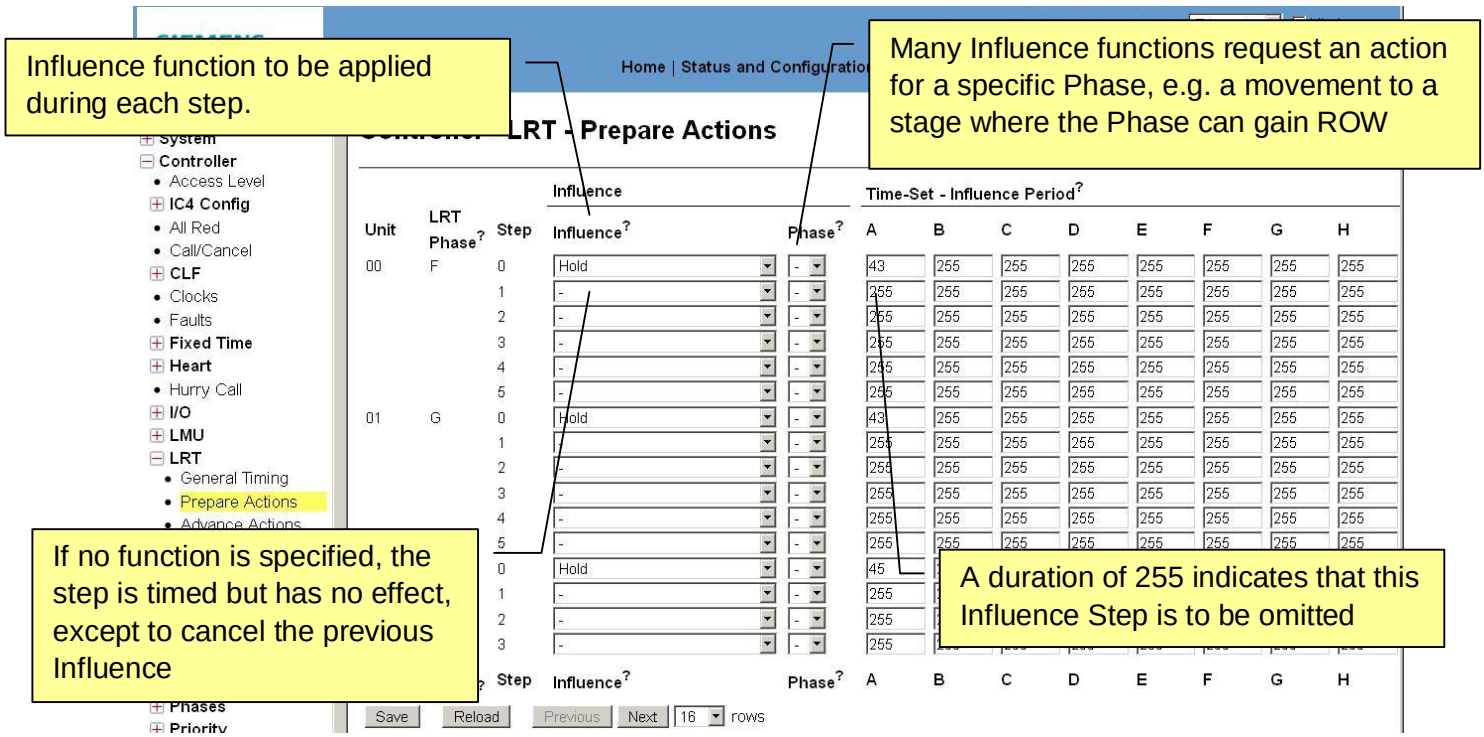


Figure 2-5 - LRT Prepare Actions

Note that the Prepare and Advance Actions web pages have the same layout.

2.5.1 INFLUENCE PERIOD

The Influence Period defines the duration of the step.

The duration of each step is configurable for each Maximum Green Time Set, allowing for differing conditions during the day for example. More information on the Time Sets is in section 2.18.

When the duration of a step completes, the influence function for the next step is applied and continues for the duration of this new step. Normally the influence of the previous step ceases. However, if the specified influence function for the new step is an “Add …” function, the two influence functions are combined and continue to the duration of the new step.

If the Influence Period for a step is zero, the influence is still applied (briefly) before the influence for the next step is applied; useful when the following step uses an ‘Add’ function for example.

If an influence is not required at certain times of day, then the Influence Period for the Time Set should be set to 255 and then that step will be omitted (while that Time Set is active).

When all the steps have been executed, any request for LRT mode from these influences is removed, although any latched VA demands for phases will remain until serviced.

2.5.2 INFLUENCE FUNCTIONS

The available influence functions are listed below. Unless stated otherwise, each function requests LRT mode in order to influence the operation of the controller.

- ***LRT Request*** – Generates an unlatched LRT Request for the duration of this influence (see section 2.7). It also inserts a latched VA demand for the LRT Phase associated with the LRT Unit. Any phase specified with this influence is ignored. This normally means right of way moves to give the LRT Phase right of way.
- ***Immediate Move*** – Requests that the next stage containing the specified influence phase gains ROW and then holds. All phase green extensions are ignored. If it is required to bring the LRT Phase to ROW ready for the tram, then consider using the LRT Request influence instead of this Immediate Move influence.
- ***Add Immediate Move*** – Add the specified influence phase to the existing Immediate Move influence, so any stage containing any of the specified phases can gain ROW; see the 'Add Move' general notes in section 2.5.3.
- ***Demand-Dependent Move*** – Request the next stage in which the specified phase can gain ROW if there is a demand for that stage, or a demand for one of the phases within the stage. All VA demands are considered, but all phase green extensions are ignored, in contrast with the Allow Move influence. Once the specified phase gains right of way, no further moves are considered. While there are no demands present for any stage containing the specified phase, ROW remains on the current stage.
- ***Add Demand-Dependent Move*** – Add the specified influence phase to the existing Demand-Dependent Move influence, so any stage containing any of the specified phases can gain ROW; see the 'Add Move' general notes in section 2.5.3.
- ***Hold*** – Prevents all stage changes in the stream containing the LRT Phase associated with this LRT Unit. Any phase specified with this influence is ignored. Stage moves in progress are allowed to complete. This is typically used to prevent any further stages so the controller is ready to react to the tram when it gets closer to the intersection. Instead of a Hold, consider using an Allow Move so ROW can move from the current

stage to the stage ready for the tram if there are no extensions active for the current stage and their other demands are present for the stage that also gives the tram right of way.

- ***Allow Move*** – If there is a demand for a stage (or phases within the stage) in which the specified phase can gain right of way and there are no phase green extensions active for phases that need to terminate, then ROW will move to that stage and then hold. Maximum green times are ignored. If the specified phase can appear in more than one stage, the stage selected is based on the standard next stage selection rules (similar to VA mode). This influence can be used to allow a move to a stage in which the LRT Phase can gain right of way if there are other demands present, without forcing the current stage to terminate. This influence is similar to the CLF influence 'Prevent, except…'
- ***Add Allow Move*** – Add the specified phase to the existing Allow Move influence, so any stage containing any of the specified phases can gain ROW; see the 'Add Move' general notes in section 2.5.3.
- ***Add Phase Demand*** – Adds a latched VA demand for the specified phase without cancelling the previous influence. If no previous influence is active, this influence does **not** request LRT mode.
- ***Revoke LRT Mode*** (shown as a dash on the web page) – The Influence is timed, but has no effect on the operation of the controller, except to cancel the previous influence and remove any request for LRT mode. Note that a delay between an input changing state and the actions being triggered can be configured (see Figure 2-4) and should be used in preference to specifying this influence as the first step.

All the influence functions only affect the operation of the controller if LRT Mode is active and the LRT Unit is not inhibited (see sections 2.12 and 2.13), except that VA demands are always inserted regardless so those demands can be taken in to account by whichever mode of operation is active.

The influence functions only affect the stage-stream in which the LRT Phase appears. If another stage-stream needs to be controlled, then Special Conditioning can be used or a second LRT Unit can be configured on that other stage-stream, triggered from the same event inputs for example.

All stage movements are subject to the usual minimum green timings and inter-stage timings, as well as the stage movement rules configured for LRT mode, e.g. alternate stage moves. Stage movements will be delayed if the controller had already started a stage movement before the influence came in to affect.

All influence functions that hold the controller in the current stage must be used with caution if the controller is also configured to make alternate moves through an all-red stage since these may trap the controller in the all-red condition for an extended period. A work-around would be to temporarily disable LRT mode while the all-red stage is at right of way for example.

2.5.3 'ADD MOVE' INFLUENCES

The ‘Add Immediate Move’, ‘Add Demand-Dependent Move’ and ‘Add Allow Move’ influence functions add an additional phase to the existing stage move influence function, allowing the controller to select additional stages.

Tip! The ‘Add … Move’ influence functions shouldn’t be needed just because the phase can gain ROW in two or more stages. All the influence functions are phase-based so a single Immediate Move function for example causes the controller to automatically select the best stage in which the phase can gain ROW so an ‘Add Immediate Move’ function is not required.

All the 'Add Move' influences use the standard next stage selection rules (as used by VA mode etc.), except they ignore all the stages that do not contain any of the phases specified by the influences. The only stages considered for the next stage will be those containing one or more of the phases specified. As required by the stage selection rules, ROW will not be permitted to skip a stage that contains one or more of the specified phases and includes a phase that is demanded (by any VA demand), unless that phase can gain ROW in the stage selected. Once a stage that includes any of the specified phases gains ROW, it is held at ROW and no further stage moves are considered (while the influence remains active).

2.6 STOPLINE PRESENCE ACTIONS

If the LRT phase is not at right of way when the Stopline Presence Actions are triggered, then this could be because the Prepare and Advance Events were missed or because the tram was delayed in reaching the Stopline. In either case, the tram now requires right-of-way through the junction and so the following actions are performed:

- The Prepare and Advance Influences are terminated
- A latched VA demand for the LRT Phase is inserted
- The ‘Stopline Influence Period’ timer is started
- An LRT Request influence is inserted for the duration of the ‘Stopline Influence Period’

These actions request LRT mode and attempt to bring the LRT Phase to right of way. If the configurable Stopline Influence Period is set to zero, the LRT Request influence is not applied (and LRT mode is not requested) so only the latched VA demand for the LRT Phase is inserted.

Even if the LRT Phase is already at ROW, these actions are taken to ensure an LRT Request is inserted so the appropriate LRT functions are introduced in case the Advance Event is not configured to insert an LRT Request.

When the Stopline Influence Period expires, the LRT Request and the LRT phase extension are removed if the LRT Phase did not appear at right of way. In this case, only the VA demand for the LRT Phase persists, optionally with phase-extensions.

While the input for the Stopline Presence Event remains active, a continuous unlatched demand for the LRT Phase is inserted. The unlatched demand for the phase will be removed when the input goes inactive.

Why 'unlatched'? It is an 'unlatched' demand to handle the case where the Stopline Presence Event input remains active for a short period after the Stopline Cleared Event or Cancel Events. The LRT Phase only needs to be requested while the input remains active. The LRT Phase would be re-requested if this demand were latched.

If it is required that the Stopline Presence Event input inserts a latched demand and/or phase green extensions continuously while it is active, the input must be configured to insert a normal demand and/or extensions for the phase (on the IC4 screen 'VA Demand and Extend Definitions' for example).

Note that the Stopline Influence Period is set on the General Timing web page, see Figure 2-4.

2.7 LRT REQUEST INFLUENCE

The LRT Request Influence function inserts a VA demand for the LRT Phase, inserts a High Priority request for the LRT Unit that requests LRT Mode, and requests an immediate move to the next stage that allows the LRT Phase to gain right of way.

An LRT Request can be triggered by:

- The Advance influence steps for example,
- The Stopline Presence Action
- A revertive LRT Request can also be configured to be inserted should the Cancel Event not occur and the Cancel Timeout period expires.

When the LRT Phase gains ROW while the influence period for the LRT Request is active, the LRT Request is latched and remains active until the Stopline Cleared Actions or Cancel Actions are triggered. This latched LRT Request inserts green extensions for the LRT Phase. This is the normal sequence of events and the appearance of the LRT Phase is controlled as described in section 2.11.5.

However, if the LRT Phase does not gain ROW within the defined influence period, because a higher priority mode or another LRT Unit is active for example, the high priority request for LRT mode is cancelled:

- If the LRT Request influence period in the Advance Actions expires, the Stopline Presence Actions will trigger the LRT Request again when the tram triggers the Stopline Presence Event.
- If the Stopline Influence Period from the Stopline Presence Action expires, then no high priority request will remain but the latched VA demand for the LRT Phase will remain to be serviced like any normal phase demand.

If required, the 'Stopline Influence Period' time should be set long enough so the LRT Request is still active after the servicing of other LRT Phases completes so this delayed tram is not delayed further.

The Stopline Influence Period is terminated by the Stopline Cleared Actions and by the Cancel Actions (because of a Cancel Event or the Cancel Timeout period). It is not terminated when the LRT Phase gains ROW nor when it loses ROW. It will continue to time in order that the LRT Phase is re-requested should it not complete correctly, i.e. the Cancel

Actions are not triggered because the tram is still at the stopline. Remember that an LRT Phase may be terminated early if a higher priority mode or LRT Unit is active.

2.8 STOPLINE CLEARED ACTIONS

If a Stopline Cleared Event is not configured, then the LRT Phase will normally remain at right of way until the Cancel Actions occur (or its maximum green timer expires, see section 2.11.5).

If a Stopline Cleared Event is configured, the Stopline Cleared Actions will remove the green extensions and terminate the LRT Phase. If the phase is at right of way in a stage with other phases, the LRT phase is terminated while those other phases remain at right of way. This uses the same mechanism as the terminate after min green facility.

After the LRT Phase is terminated, control will either revert to the next highest requested mode of control or else continue in LRT mode in order to service any remaining requests for LRT mode from other LRT Units. The new mode can select the next stage to gain ROW, while Intergreen Delays control the appearance of phases gaining right of way. See section 2.11.5 for more information.

If a dedicated Stopline Cleared Event input is not available, the Stopline Cleared Event can be triggered by the trailing edge of the same input that triggers the Stopline Presence Event (see Screen - LRT Detector States in the IC4 Help), or even a Event Delay period after the leading edge of that input (see Figure 2-4).

2.9 CANCEL ACTIONS

The Cancel Actions are triggered by the Cancel Event (after a configurable Event Delay) or when the Cancel Timeout period expires.

The Cancel Actions will always cancel a latched LRT Request if still active. They will also cancel any influences still active and the extensions for the LRT Phase, terminating the phase green extensions and the Intergreen Delay.

Control reverts either to the next highest requested mode of control or else continue in LRT mode in order to service any remaining requests for LRT mode from other LRT Units.

Any latched VA demand for the LRT Phase will have been cancelled automatically as soon as the LRT Phase appeared at right of way. If the LRT Phase has not appeared at ROW, the VA demand for the phase persists to be serviced by lower priority modes.

An LRT Request inserts continuous green extensions for the phase. A Cancel Timeout period for the LRT unit is used to limit the continuous extension in case the Cancel Event does not occur, regardless of the mode of operation.

The Cancel Timeout period runs while opposing demands are present (and is cancelled if the opposing demands cease) to limit the duration of the LRT Phase while opposing demands are present, just like a phase maximum green timer.

Once the LRT Phase has terminated, the Cancel Timeout period continues whether there are any opposing demands or not to prevent the controller remaining in an all-red state for a prolonged period. When the Cancel Event occurs (and after its configurable Event Delay) the Cancel Timeout period stops.

Common Mistake: if the Cancel Timeout period is set to zero, the Cancel Actions will be deemed to have expired as soon as an opposing demand appears, invoking the Cancel Actions and thus cancelling any intergreen extensions.

If the Cancel Event does not occur and the Cancel Timeout period expires, a revertive LRT Request, latched phase demand and/or continuous extensions* for the LRT Phase can be configured to be inserted, as well as the normal Cancel Actions (above). (* Continuous green extensions for the LRT Phase are inserted next time the LRT Phase gains ROW)

When the LRT phase regains ROW, the Cancel Timeout period is restarted if a revertive LRT Request or continuous extensions are requested. If Cancel Timeout period expires a second time, the LRT unit is cancelled (as usual) but the configured revertive actions are not applied again. This is to prevent the LRT unit being demanded repeatedly simply because one real Cancel Event was missed.

Note that the Stopline Presence Event input (or any other digital input) can be configured to insert demands and/or extensions for the LRT Phase in order to continually request and/or extend the LRT Phase (see section 2.6) and this can be used in preference to the revertive phase demand and extension.

2.10 LRT INTERGREEN DELAYS

The LRT Facility makes use of the standard Intergreen Delay facility in order to prevent selected phases gaining ROW while the tram is still crossing the intersection after the LRT Phase has been terminated. By default, all the phases that conflict with the LRT Phase are delay, but this can be modified. The appearance of one or more non-conflicting phases can also be delayed.

To make use of the Intergreen Delay facility, the special conditioning mnemonics *LRT0IGD, *LRT1IGD, etc, can be entered in the IC4 Intergreen Delays screen, as shown in Figure 2-6; the number within the mnemonic identifies the LRT unit.

The Losing Phase is should be set to the LRT Phase. Initially, the list of Gaining Phases to be delayed is automatically populated with the list of phases that conflict with the specified Losing Phase, but this list can be manually modified to include non-conflicting phases for example.

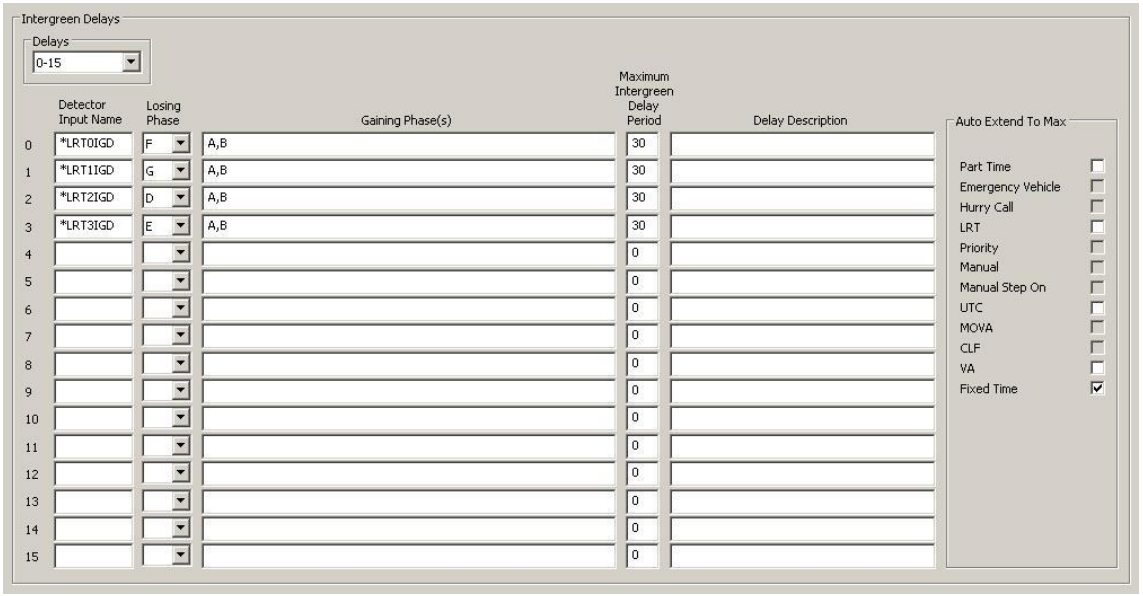


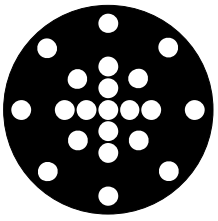
Figure 2-6 - LRT use of Intergreen Delay Flags

For more information of this standard facility, refer to the controller's facilities handbook or the IC4 Help.

2.11 LRT PHASE APPEARANCE

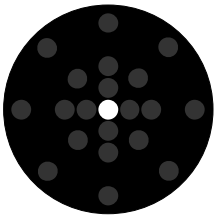
2.11.1 TRAM INDICATORS

The figures below show a typical tram signal, made up of a single round black signal that contains a number of individual white lights that make up each aspect.

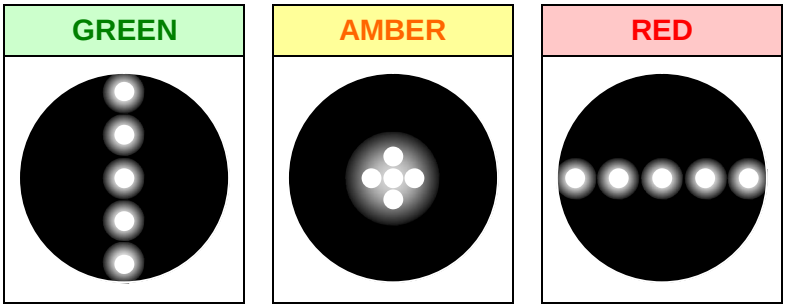


The part numbers for the Siemens LRT Signal Heads can be found in the Helios General Handbook, see Appendix E of Related Documents c).

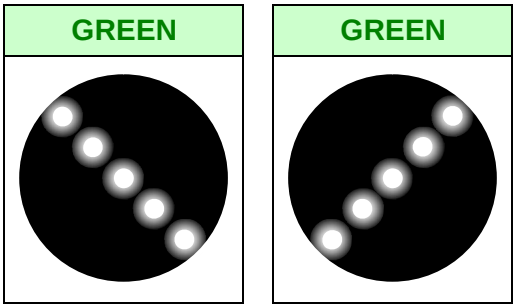
A single central indicator dot is common to all the signal displays and normally remains illuminated while the controller is powered and running normally. This is typically driven from a Switched Sign output and controlled by Special Conditioning to give the most flexibility as to when this central spot signal is extinguished.



The Proceed Ahead vertical bar is driven from the Controller's Green phase output, the Stop/Give-Way circle is driven from the Amber and the Stop horizontal bar is driven from the Controller's Red phase output.



Instead of the Proceed Ahead vertical bar signal, the Green phase output can drive either a Proceed Left or Proceed Right diagonal bar signal (shown below).



Where two or more LRT Phases use one tram signal, one illuminating the Proceed Left signal and one illuminating the Proceed Right signal for example, an additional phase and the LRT Phase Groups feature is typically required to drive the common Red and Amber, Stop and Give-Way aspects.

2.11.2 LRT PHASE GROUPS

In order to correctly control two or three green 'proceed' aspects (phases) with one amber and one red aspect, LRT Phases may be grouped together into a single LRT Phase Group.

Care must be taken when configuring LRT Phase Groups:

- The red and amber aspects for the first phase in the group will be the only red and amber aspects illuminated for the whole LRT Group.
- The first phase in the group defines the Red Lamp Monitoring actions for the LRT Group.
- Ensure that all the LRT Phases in a group never gain ROW at the same time, and that there is an adequate intergreen period between the phases in the group to ensure that the amber leaving period can complete before another LRT Phase in the group gains ROW.
- During the start-up sequence, it is recommended that all phases in an LRT Group start-up to not at right of way (Red / Stop), not ROW (Green / Proceed).
- The first phase in an LRT Group defines the phases that conflict with the LRT Amber aspect for green/amber conflict checking. If it is required that a traffic phase (for

example) runs in parallel with one LRT Phase in an LRT Group, but also conflicts with another LRT Phase in the same group, care must be taken if Green/Amber conflicting is required, see below.

If it is required that green/amber conflicts are required, then consider the following:

Remember that Amber conflicting monitoring can be disabled in the Lamp Sequence if not required.

The problems occur because all the LRT Phases in the Group use the same Amber, so whichever LRT Phase loses ROW the amber for the first LRT Phase in the group will illuminate and the Green/Amber conflict checks for that phase will be applied.

If green/amber conflict monitoring is required with an LRT Phase Group then add an additional phase as the first in the LRT group that is only used to provide the common red and amber, with the green not used. This new phase must be configured to NOT gain ROW in any stage and should never be demanded to gain ROW.

As this phase will never illuminate its green, change the Sensor Type from R,G,A to R,A,xG on the Lamp Monitoring screen in IC4. Note that the phase should still be configured to use the same LRT Lamp Sequence as the 'real' LRT Phases.

The controller checks for conflicts between the amber of this first phase and the greens of all phases configured to conflict with that first phase. For each LRT phase green (the second and subsequence phases in the group), the controller also checks for conflicts between that LRT green (proceed) and the greens and ambers of all phases configured to conflict with that LRT phase.

2.11.3 RECOMMENDED LRT LAMP SEQUENCE

It is recommended that a unique Lamp Sequence is specified in IC4 to drive the tram signals, see Screen - Lamp Sequences in IC4.

For the UK, the controller's standard UK vehicle traffic Lamp Sequence may be copied and modified, with the starting red/amber period removed and the duration of the amber leaving period lengthened as required. See Figure 2-7:

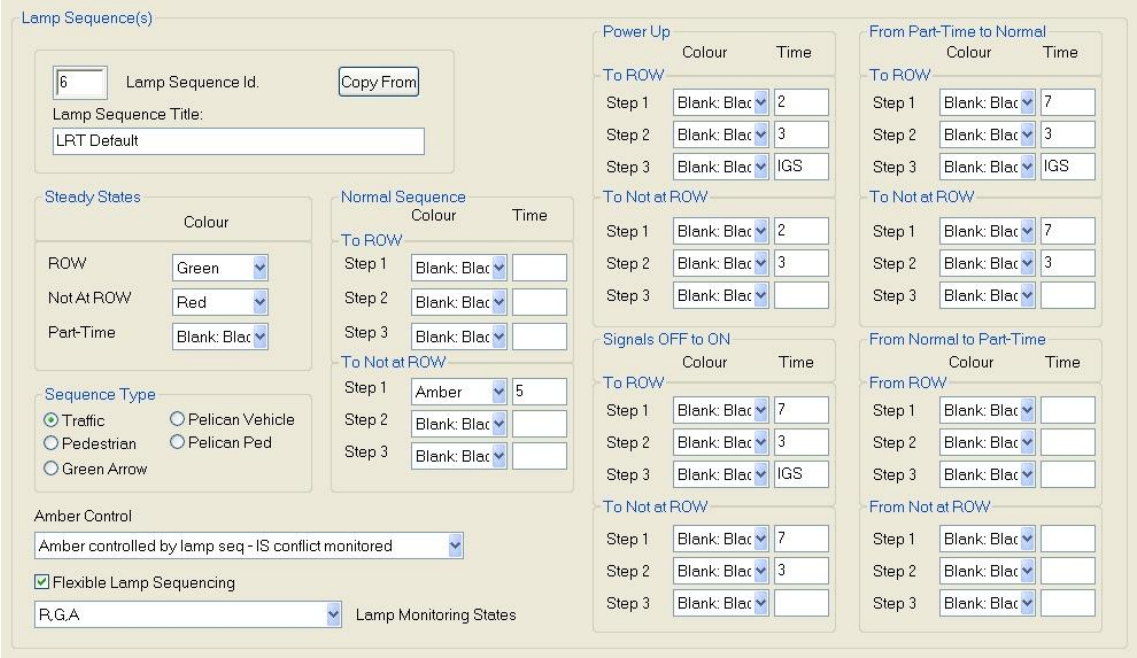


Figure 2-7 - Recommended UK Tram Lamp Sequence

Note the following:

The Amber Leaving Time is explicitly stated as five seconds rather than making use of LAT. This is to avoid having to leave the Non-UK box ticked on the IC4 Facilities screen. If the LAT option were used then different periods for different phases and timesets could be specified.

All the start-up step colours are shown here as blank (phase remains extinguished). To ensure the LRT Phases appear at red/stop at the same time as other phases appear at red, the start-up step timings need to match those used on other lamp sequences.

Flexible Lamp Sequencing needs to be enabled to allow the automatic return to green should a second tram appear while ROW remained in the same stage that allowed the first tram to gain ROW.

2.11.4 APPEARANCE IN A STAGE

If an LRT Phase appears in a stage with other phases it will typically be configured as optional and demand-dependent and will only appear at right of way if demanded. The usual phase appearance type options can be configured, but Type 2 is recommended so the phase can appear at any time during the stage'

If the LRT Phase appears in a stage with no other phases, it should be configured as fixed in the stage and appearance Type 0 (always appears). The stage itself will only appear if the LRT phase is demanded or the stage is explicitly demanded (by modes of operation such as UTC or CLF for example).

If only LRT Phases appear in a stage and it is required that all are optional and demand-dependent, then a fixed (not optional) dummy phase must be configured in the stage.

2.11.5 LRT PHASE EXTENSIONS

An LRT Phase may gain right of way, whether LRT is the active mode of operation or not.

If LRT mode of operation is not active, the stage in which an LRT Phase appears will terminate subject only to the normal rules of operation for that mode. The LRT Phase may therefore terminate before the Stopline Cleared or Cancel Events are triggered for example.

Regardless of whether LRT mode of operation is active, if an LRT Phase with an LRT Request gains right of way, even if the LRT unit is being ignored because of a previous LRT unit:

- While the LRT Phase is at right of way, normal phase green extensions for the phase will be inserted continuously until either of the following occur:
  - the Stopline Cleared Actions occur (if configured), or
  - the Cancel Actions occur (from the Cancel Event or Cancel Timeout period),

  Note: The phase green extensions may be ignored by the current mode of operation.
- The LRT Phase will be requested to terminate when any of the following occur:
  - the Stopline Cleared Actions occur (if configured),
  - the Cancel Actions occur (from the Cancel Event or Cancel Timeout period), or
  - the maximum green time for the LRT Phase expires

  Common Mistake: If the maximum green period for the LRT Phase is set to zero, the LRT Phase always terminates when its minimum green period expires, regardless of the Stopline Cleared Event.
- When the LRT Phase terminates, Intergreen Delays for the LRT Phase delay the appearance of conflicting phases until the following occurs:
  - the Cancel Actions occur (from the Cancel Event or Cancel Timeout period)

  Note: These Intergreen Delays are applied in all modes of operation to prevent conflicting phases gaining right of way while the tram is still crossing the intersection.

If there was no LRT Request and only demands and/or extensions are inserted for the LRT Phase, then the above does not apply and the phase appearance and termination is controlled in the same way as for other phases.

Any time an LRT Phase with an LRT Request is terminated, the intergreen periods between the LRT Phase and the specified phases in the next stage are extended until the Cancel Actions are triggered, cancelling the LRT Request. The Intergreen Delay operates independently of any stage-to-stage movement.

2.12 LRT PRIORITY AND HANDLING OF MULTIPLE REQUESTS

Requests for LRT mode from more than one LRT unit will normally be served on a first come, first served basis subject to the controller remaining in LRT mode. Exceptionally it is possible in Special Conditioning to inhibit the first LRT unit when events for a second LRT unit are received.

This first come, first served priority logic is not triggered by LRT Events but by LRT Actions that request LRT mode, i.e. high and medium priority influences. By ignoring the initial input and event and waiting for the first significant actions, the long delays configured when a distant tram triggers an input, will not delay a second tram that requests immediate ROW when it tries to leave a near-by station. In this example, the tram at the near-by station is the first real request, and the distant tram will be treated as the second tram automatically.

While the controller is in LRT mode servicing one LRT unit, events from other LRT units will cause the configured delays and sequence of timed influences to be run, but the action will normally be ignored, except that any VA demands inserted will be stored and serviced when appropriate.

However, if a second LRT unit inserts a higher priority influence than the first LRT unit, the second LRT unit gains control.

The Prepare and Advance Influences (section 2.5) are divided in to three priority groups. The LRT Request from the Stopline Presence Actions (section 2.6) is included in this priority logic.

- High priority influence functions:
  - LRT Request
  - Immediate Move
  - Demand-Dependent Move
- Medium priority influence functions:
  - Hold
  - Allow Move
- Low priority influence functions:
  - Add Latched Demand

Thus, if the first LRT unit has only applied a Hold or Allow Move influence, then a second LRT unit will gain control if it inserts an LRT Request, Immediate Move or Demand-Dependent Move. If the second LRT unit requests an influence of equal or lower priority, it does not gain control.

Phase demands do not request LRT mode of operation and so are automatically treated as the lowest priority, and are not actioned on a ‘first come, first served’ basis.

Under some conditions, such as when the normal sequence of events does not occur, then a configured timeout can expire and the servicing of the active LRT unit is suspended. Any other requests for LRT Mode can then be serviced. One example would be when the Prepare Event occurs but then this is not followed by an Advance Event. When the sequence of timed influences initiated by the Prepare Event is completed and still no

Advance Event has occurred, the controller will terminate the processing for that LRT unit and service other requests.

It should be noted that if LRT mode of operation is active, demands for other phases (including other LRT phases) are ignored unless demand-dependent influences are used. If an 'ignored' LRT Phase does appear at right of way outside of the Overlap Window Period (described below) while the controller is processing its 'first' LRT unit, then the appearance of the 'ignored' LRT Phase is controlled as though LRT mode is not active (see section 2.11.5). Therefore, the 'ignored' LRT Phase may terminate if an Immediate Move is requested by the 'first' LRT unit for example.

When an LRT phase gains right-of-way, a configurable Overlap Window Period is started. Demands and LRT Requests for other LRT phases in the same stage can be serviced during this Overlap Window Period. Figure 2-8 shows a typical sequence where a second LRT phase is allowed and appears alongside the first LRT phase. An LRT Request for a phase that does not gain right of way in the current stage remains inhibited by the first come / first served logic, so LRT phases that do not gain right of way in the same stage are mutually exclusive and cannot gain right of way together during the Overlap Window Period.

If a second LRT unit gains right of way during the Overlap Window Period, the Stopline and Cancel Events for both LRT units are processed as normal – both LRT units are considered to be active at the same time. The two LRT phases may terminate at different times and LRT mode will continue until both LRT units have completed.

When the Overlap Window Period expires, the servicing of all other LRT units is inhibited again until the active LRT unit(s) complete. In addition, an Overlap Inhibit Period will inhibit the configured units for a period that starts when the Overlap Window Period expires.

Note: To prevent other LRT Phases from gaining ROW late in the current stage (and extending the stage any further), use the standard Phase Appearance Type 3 feature to prevent their appearance after a configurable stage window period. The various inhibit and priority mechanisms do not prevent demanded LRT Phases appearing at ROW in the current stage. They just prevent LRT units taking control of the intersection.

The servicing of the LRT Phase is considered complete when the Cancel Action has been triggered. Then any active requests for LRT Mode are serviced, in the order in which they have been received, subject to the active Overlap Inhibit Period.

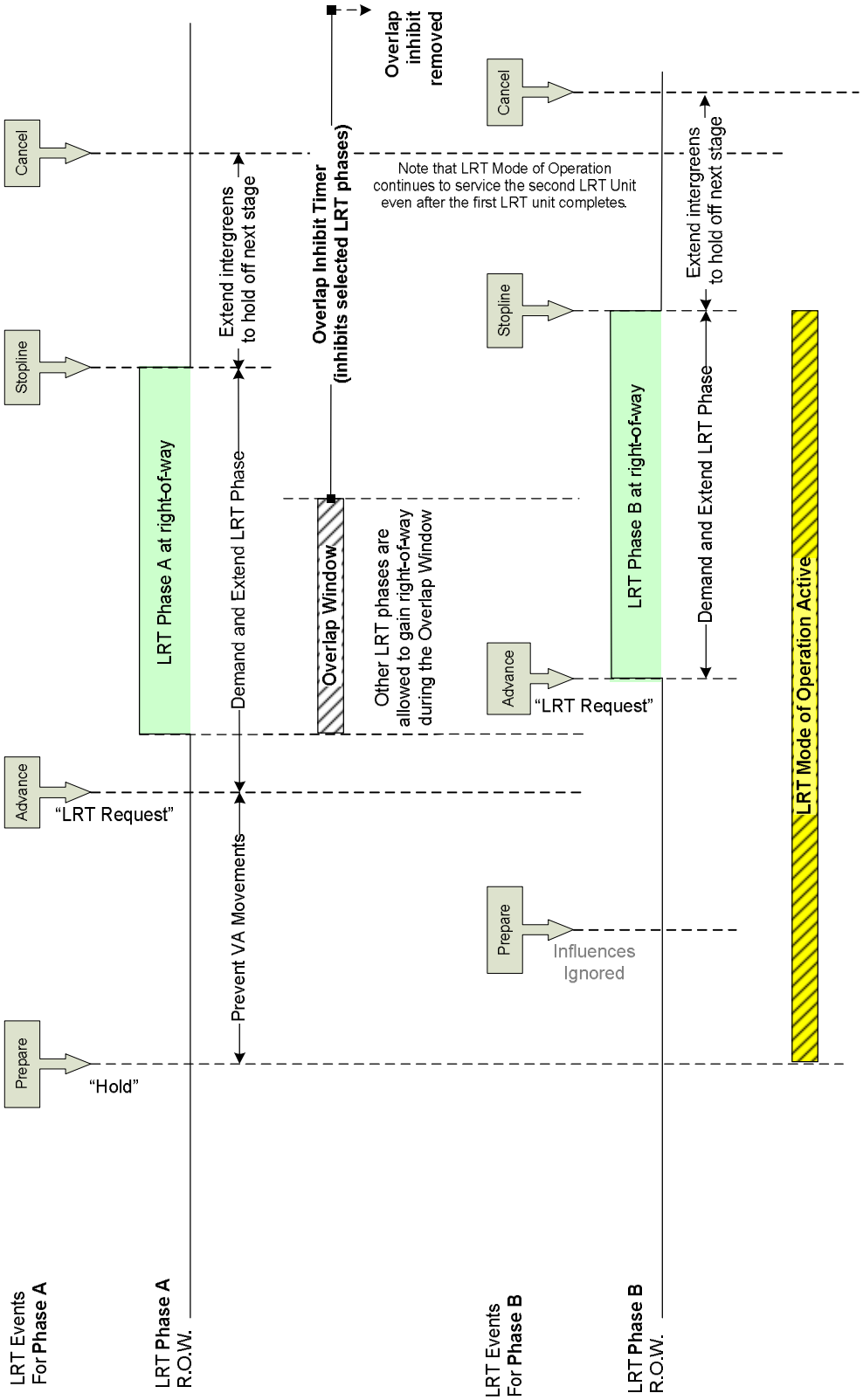


Figure 2-8 - Overlap Window Operation

2.13 FOLLOWING TRAMS

The servicing of several closely following trams on the same LRT unit can be controlled via a configurable Following Inhibit Period.

When the LRT Phase terminates after gaining ROW due to an LRT Request, the Following Inhibit Period is started and any further Prepare or Advance Events for the same LRT unit are timed but the influences have no effect on the controller until the Following Inhibit Period has expired.

This prevents the second tram on the same LRT unit from immediately taking control of the intersection shortly after the first tram and consequently avoids delaying other traffic any further. It is usually preferred that this second tram is made to wait at the intersection to allow other the traffic movements, on the basis that the second tram is likely to be delayed by later tram signals because of its proximity to the first tram on the same line.

Should the first tram not reach the intersection in the expected time, mechanisms are in place to avoid the Following Inhibit Period delaying that tram any further.

If the first tram has not yet triggered an LRT Request or the LRT Phase does not gain ROW, the Following Inhibit Period is not started. Therefore, if Influences expire and the LRT Phase was never requested, this inhibit period does not start and the tram is in not inhibited.

If the LRT Phase gains ROW due to an LRT Request from an Advance Influence, and then terminates without the tram reaching the intersection, the new LRT Request inserted by the Stopline Presence Actions when the tram eventually reaches the stopline will be accepted. The controller remembers that the LRT Request was inserted by timed Influences and no Stopline Presence Event was detected, and thus it permits the LRT Request triggered by the Stopline Presence Actions to cancel the inhibit period.

As a result, a delayed tram is not inhibited by this timer even though Prepare and Advance actions may have been executed. However, as required, a second tram triggering the same LRT Phase will be delayed by this configurable Following Inhibit Period.

Once the Following Inhibit Period expires, the second tram is permitted to take control of the intersection and thus gain ROW, unless it has already gained ROW as part of the normal stage sequencing and its Cancel Event has been triggered.

On the odd occasion that there are no opposing demands after the LRT Phase first terminates, then the stage in which the LRT Phase can appear will remain at right of way. If a second demand for the LRT Phase appears after the LRT Phase has been terminated, right of way needs to move off the current stage and back before the LRT Phase can gain right of way again.

2.14 LRT STAGE SEQUENCING AND RESUMING NORMAL OPERATION

The controller will typically be configured to allow movement to the stage containing the LRT Phase from any other stage, thus interrupting the normal cyclic order of demand servicing.

When the LRT movement has been serviced, by default the controller will resume servicing demands from after the LRT stage.

In order to try to resume the original stage sequencing, the controller can be configured to start considering demands from the stage after that which was active when the LRT actions

first occurred. This is achieved by use of the controller's 'Exceptional Stage' feature, see Related Documents b).

Example 1 shows the normal operation of the intersection. The Stages 1 through 4 are called in sequential order, if demanded. Stage 5 is the LRT stage, which is not called unless demanded and so does not appear at right of way in the normal sequence.

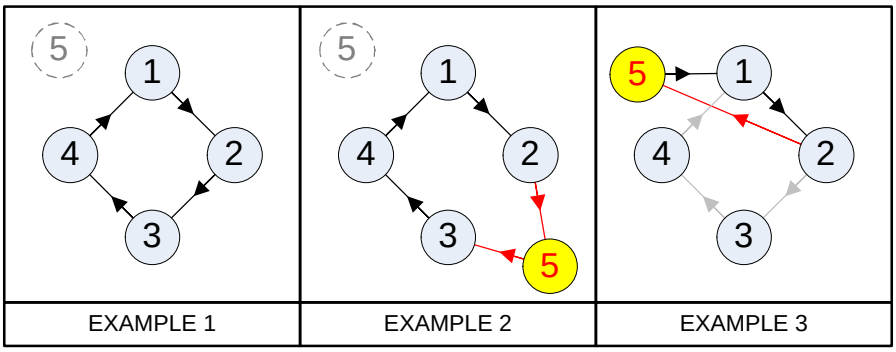


Figure 2-9 – Stage Sequence Examples 1 to 3

Examples 2 and 3 show the stage sequence if right of way jumps from Stage 2 to Stage 5 to service the LRT Stage demand.

Example 2 shows the sequence if the LRT Stage is configured as an 'Exceptional Stage'. When Stage 5 terminates, the controller will consider demands for Stage 3, then Stage 4, and so on. This attempts to resume the original stage sequencing and thus minimise delays at the intersection.

Example 3 shows the stage sequence without this feature. When Stage 5 terminates, the controller will consider demands for Stage 1, then Stage 2, and so on. It shows that Stages 3 and 4 are ‘skipped’ and Stages 1 and 2 are allowed to run again. This will therefore delay the traffic that requires Stages 3 and 4.

2.15 PHASE COMPENSATION DUE TO LRT STAGE MOVEMENTS

Any stages or phases skipped or curtailed by a stage move triggered by an LRT Unit can be compensated with extra green time when they next appear at ROW. Compensation times can be managed using the LRT Compensation Times screen, see Figure 2-10.

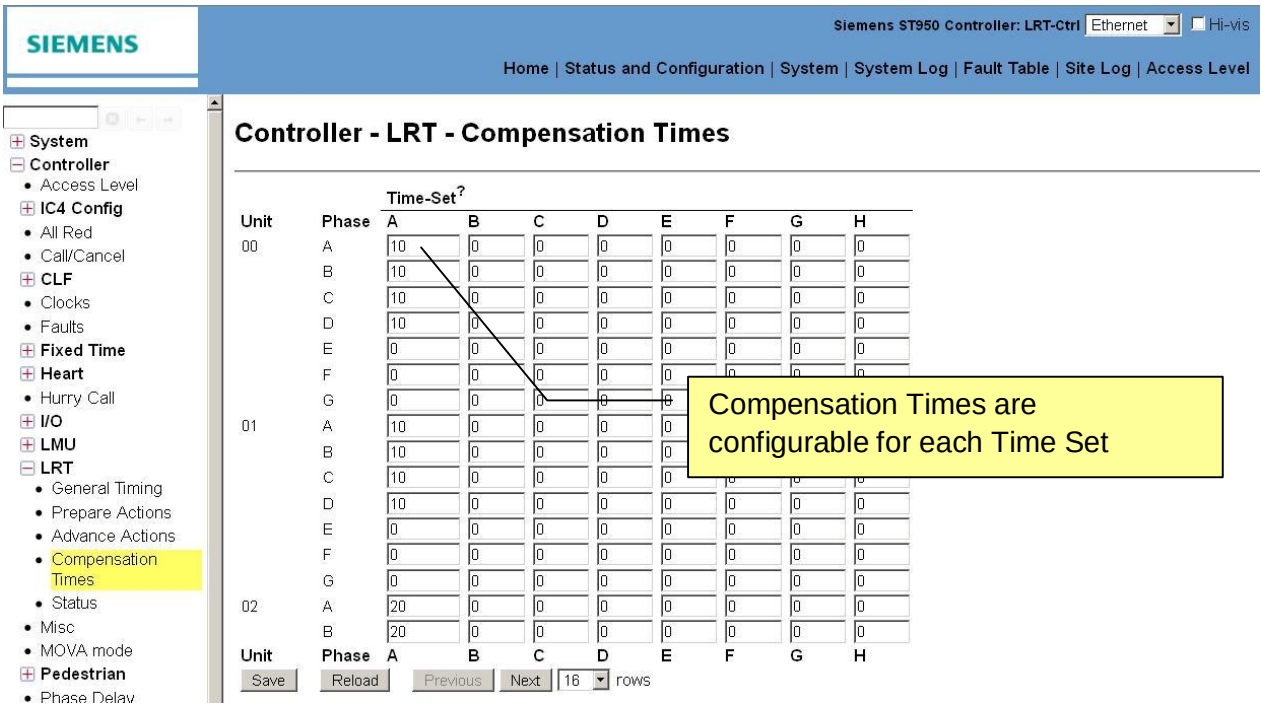


Figure 2-10 - Compensation Times

2.16 START-UP

If the signals are switched from OFF to ON, and this is configured to follow the start-up sequence, then the LRT facility is effectively reset as though the controller had just been powered on. The sequence of Events and any Influences, demands and extensions currently active are cancelled.

If a tram is trapped at a Stopline when the signals start-up, then the normal Stopline Presence Event input can be configured to demand and extend the LRT phase (see section 2.6).

LRT phases should normally only appear at ROW if demanded. If the LRT phase is configured in the start-up stage, it will automatically remain at no right-of-way if it is configured as optional in the stage and no internal start-up demand is configured.

2.17 LRT EVENT MONITORING

In addition to the usual DFM facility for input checking, the LRT Facility monitors the configured Input Detector activity and marks an LRT Event as suspect in the System Log if it occurs outside the expected sequence of Prepare, Advance, Stopline Presence, Stopline Cleared and Cancel. In addition, the Fault Table web page indicates an LRT Event Input failure.

For example, the System Log entry below indicates that the Stopline Cleared event has either occurred out-of-sequence or been missed:

```
Thu 29 Aug 2013 18:19:56 BST E(CtlrLRT) LRT unit 0, STOPLINE_CLEARED Event gone
suspect, LRT Phase F
```

A configurable fault up/down counter is employed, counting up every time the event appears suspect and down when the event occurs in the correct sequence. On returning to zero, the suspect fault log entry in the System Log is cleared. For example:

```
Thu 29 Aug 2013 18:45:25 BST N(CtlrLRT) STOPLINE_CLEARED Event no longer suspect
for LRT unit 0, LRT Phase F, auto-clear
```

If the fault up/down counter for an LRT Event reaches a configurable threshold, the particular LRT Event is marked as faulty in the System Log and any subsequent LRT Event will be ignored. For example:

```
Mon 02 Sep 2013 13:38:39 BST E(CtlrLRT) LRT unit 0, STOPLINE_PRESENCE Event gone
faulty, LRT Phase F
```

Should an LRT Event marked as faulty occur in sequence, the fault up/down counter will be decremented. Each LRT Unit can be configured to automatically clear the fault entry in the System Log if the counter returns to zero.

The RFL command (or Fault Table Reset Fault(s) button) may always be used to clear a suspect or fault indication, provided that the fault counter is below the threshold (i.e. at least one good sequence has been detected). For example:

```
Mon 02 Sep 2013 14:16:17 BST N(CtlrLRT) STOPLINE_PRESENCE Event no longer suspect
for LRT unit 0, LRT Phase F, manual-clear
```

If the Cancel Timeout period expires without the Cancel Actions being triggered by a Cancel Event, the Cancel Event will be treated as suspect and the fault up/down counter incremented. Limitation: If the Cancel Event is then triggered after the Cancel Timeout period, it is deemed as an out-of-sequence event so the fault counter may be incremented a second time.

If a fault is logged with the Prepare or Advance Events, an additional good sequence of all the configured events are required before the fault is cleared, due to these being the first events in the sequence.

Special Conditioning Mnemonics are provided to allow Special Conditioning to monitor the status of LRT Events; refer to the IC4 Help for details.

2.18 LRT TIME SETS

LRT Mode uses the same Time Sets as the Maximum Green Times. The LRT Time Sets are called up automatically when the Max Sets A to H are requested from the Timetable. LRT timing periods can be adjusted by time of day using these time sets.

VA Max Set	A	B	C	D	E	F	G	H
LRT Time Set	A	B	C	D	E	F	G	H

2.19 LRT LINKING AND STATUS INFORMATION

Special Conditioning Mnemonics are provided for the purposes of LRT control, see the IC4 Help for more details. These can be driven from UTC Control Bits for example, and provide control for the following:

- Disable the LRT Unit
- Disable LRT Events
- Trigger LRT Events
- Trigger LRT Requests
- Reset LRT Unit (cancel all timings and influences)
- Intergreen Delay Request

Special Conditioning has access to the following status information. This information can be returned to a UTC system via Reply Bits or illuminate indications on the Manual Panel for example.

- LRT Mode active
- LRT Actions active
- LRT Requests active
- LRT Influences active
- LRT Influence state
- LRT Controlling Unit
- LRT Events active
- LRT Events suspect or faulty
- LRT Unit Inhibits active

2.20 CONFIGURATION DATA

2.20.1 GENERAL LRT MODE CONFIGURATION

The following information needs to be configured for LRT mode in general:

- LRT mode needs to be enabled/disabled and assigned a priority in the mode priority table (Modes and Facilities IC4 screen).
- Alternate and ignore stage movements should be considered (Stage Prohibited, Alternate and Ignore IC4 screen).
- The “Introduction of UTC to be disabled by Priority or LRT Mode" (UTC General Data IC4 screen).
- The LRT stage can be configured as ‘exceptional’ (see section 2.14).
- Flexible Lamp Sequencing needs to be enabled to allow the controller to return to green (see section 2.11.3).
- Any grouping of LRT Phases for driving multiple tram movements on a single LRT signal head (see section 2.11.2).

2.20.2 LRT UNIT CONFIGURATION

The following general information needs to be configured for each of the 16 LRT units required:

- Identify the associated LRT phase
- Revertive LRT Request, phase demands and/or extensions (on Cancel Event Timeout)
- Any LRT Units to Inhibit when the Inhibit Period is being timed
- Event Monitoring fault threshold, count up/down values and auto-reset setting
- LRT phase minimum green periods – normal phase timing
- LRT phase maximum green periods (one per timeset) – normal phase timings

  IMPORTANT: The LRT Phase is terminated when the maximum green period expires. If the period is set to zero, the LRT Phase is terminated after its minimum green period.

The following information needs to be configured for each of the 16 LRT units for each of the eight timesets:

- Stopline Influence Period
- Cancel Timeout period
- Follow Inhibit period
- Overlap Window period
- Overlap Inhibit period (one per timeset) and phases/units inhibited
- Compensation Times

The following information needs to be configured for each of the five LRT Events for each LRT unit:

- The name of the Digital I/O Input, UTC Control Bit or Special Conditioning bit that triggers the Event (LRT Detector States IC4 screen)
- Is the Event triggered by the input going active (default) or inactive.

  Typically only used by the Stopline Cleared Event when it uses the same input as Stopline Presence.

  IMPORTANT: As is normally practice, if the input is open-circuit for detect, the input should be configured as inverted on the Input/Output screen (and not on the LRT screen) to ensure the correct polarity is used by all facilities.
- Delay required (one per timeset) between the Event and the Actions (LRT Timing Data IC4 screen)

Note that for each LRT input, the standard DFM facility needs to be configured.

The following information needs to be configured for each of the 6 influences in a sequence for the Prepare and Advance Events for each LRT unit (LRT Influence Actions IC4 screen):

- The Influence function required (with the associated phase, if applicable)
- The duration of the Influence (one per timeset)

2.21 MONITORING LRT STATUS

The LRT Status web page may be used to monitor the status of the LRT Units as trams progress across the intersection. When no trams are in the vicinity of the controlled intersection, and no LRT Units are inhibited, the LRT Status and Phase Status appear as in Figure 2-11 and Figure 2-12.

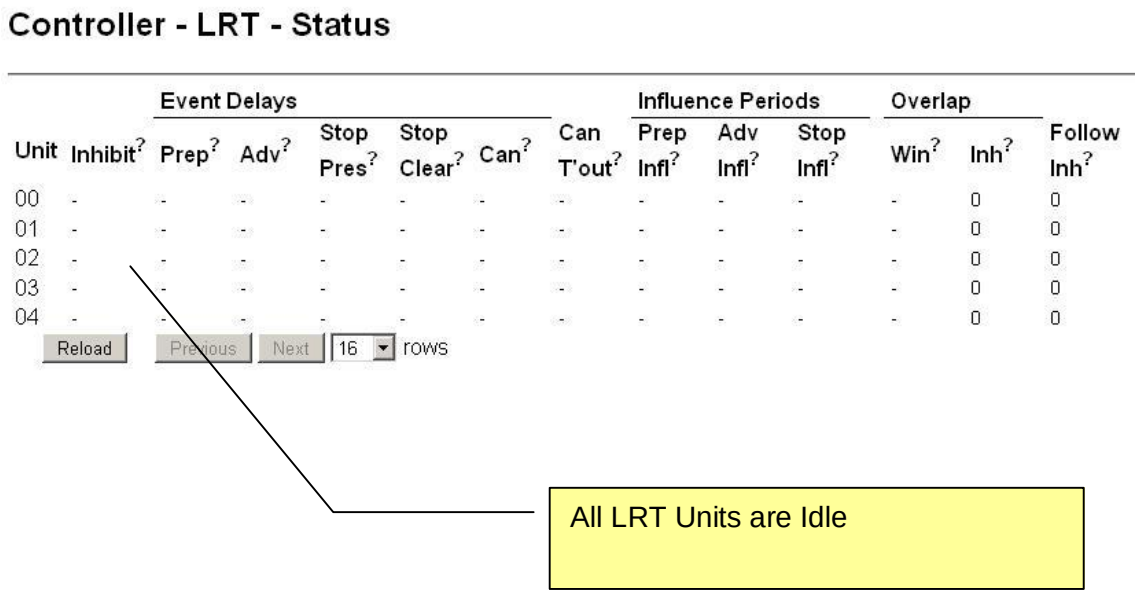


Figure 2-11 LRT Status - No Trams in vicinity

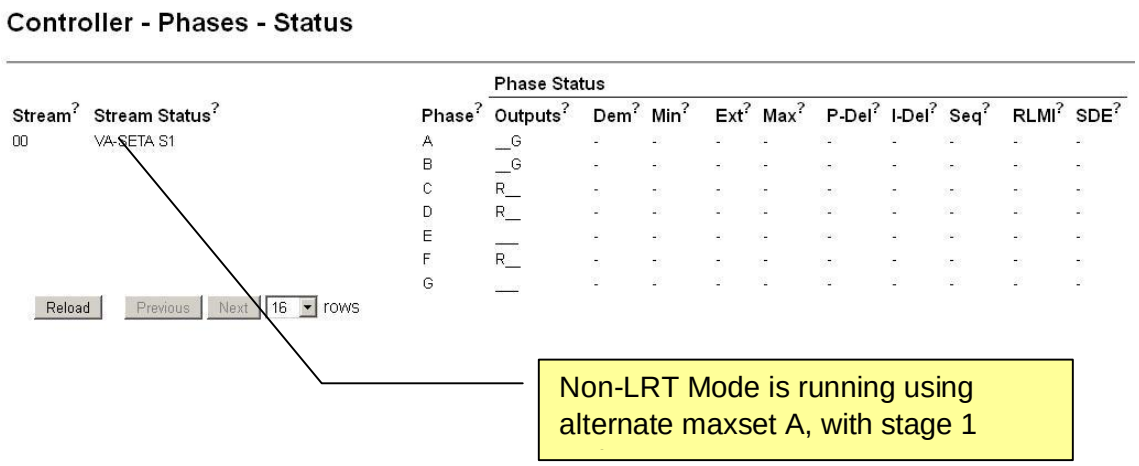


Figure 2-12 - Phase Status - No Trams in vicinity

Corresponding Handset commands:

LUS 0:----

STS 0:VA-SETA S1

For a description of the LRT related Handset Commands, see Related Documents a).

When a tram triggers an LRT Event, an Event Delay Timer is started (if configured on the General Timing web page, see Figure 2-4), and the associated Influences or Actions are started when any Event Delay expires. The Event Delay and Influence Timers are implemented as Software Timers, the status of which can be read by Special Conditioning (e.g. LDPSEC* and LDPSTU* for Prepare Event Delay) if required, see LRT Related Timers in the Timer Map in IC4 Help.

In the following example, Prepare Events have been triggered from the same Detector Input for two LRT Units.

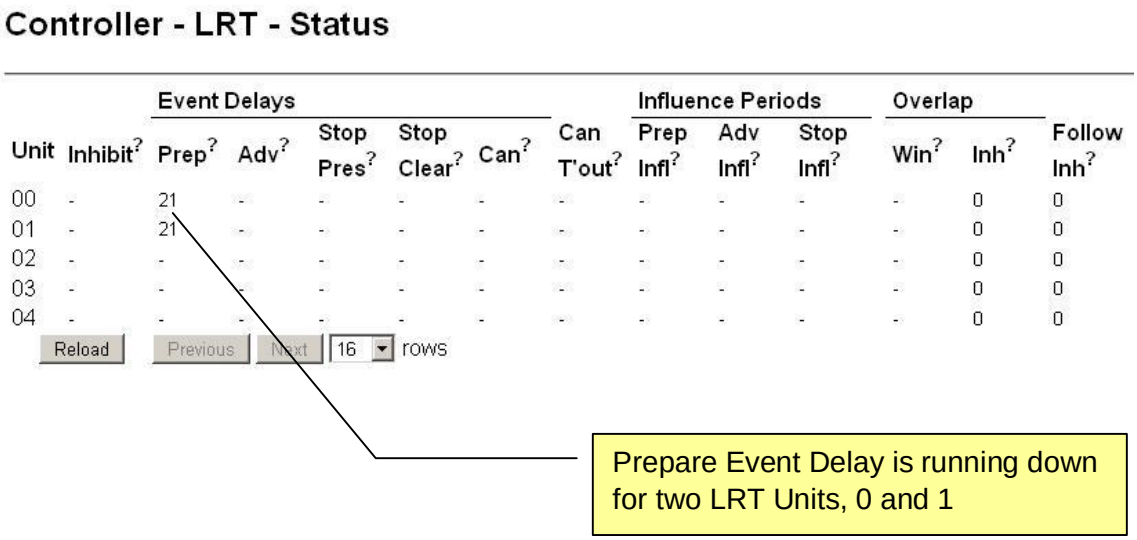


Figure 2-13 - LRT Status - Prepare Event Delay

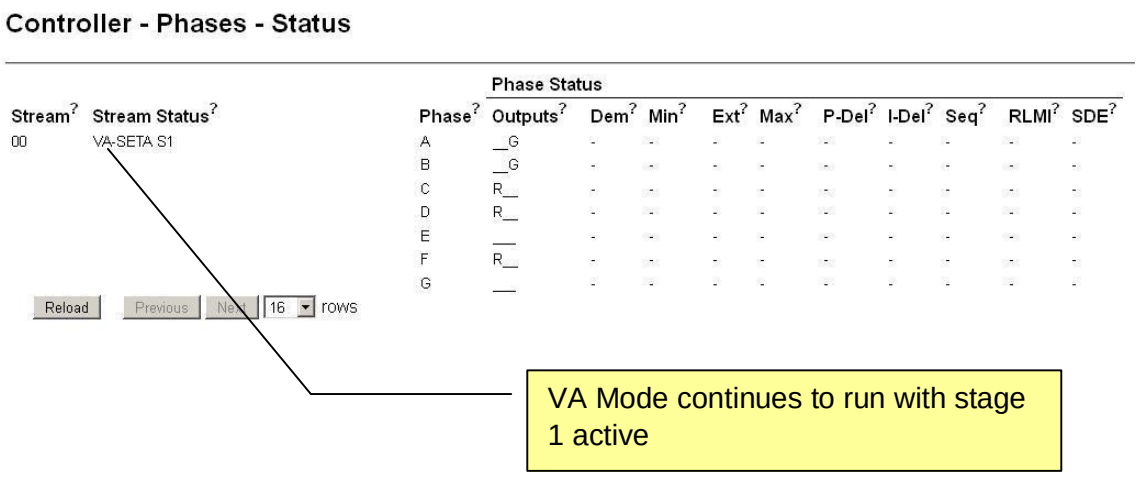


Figure 2-14 - Phase Status - Prepare Event Delay

Corresponding Handset commands:

LUS 0:P---,PR21

STS 0:VA-SETA S1

When the Prepare Event Delay expires, the Prepare Influences commence.

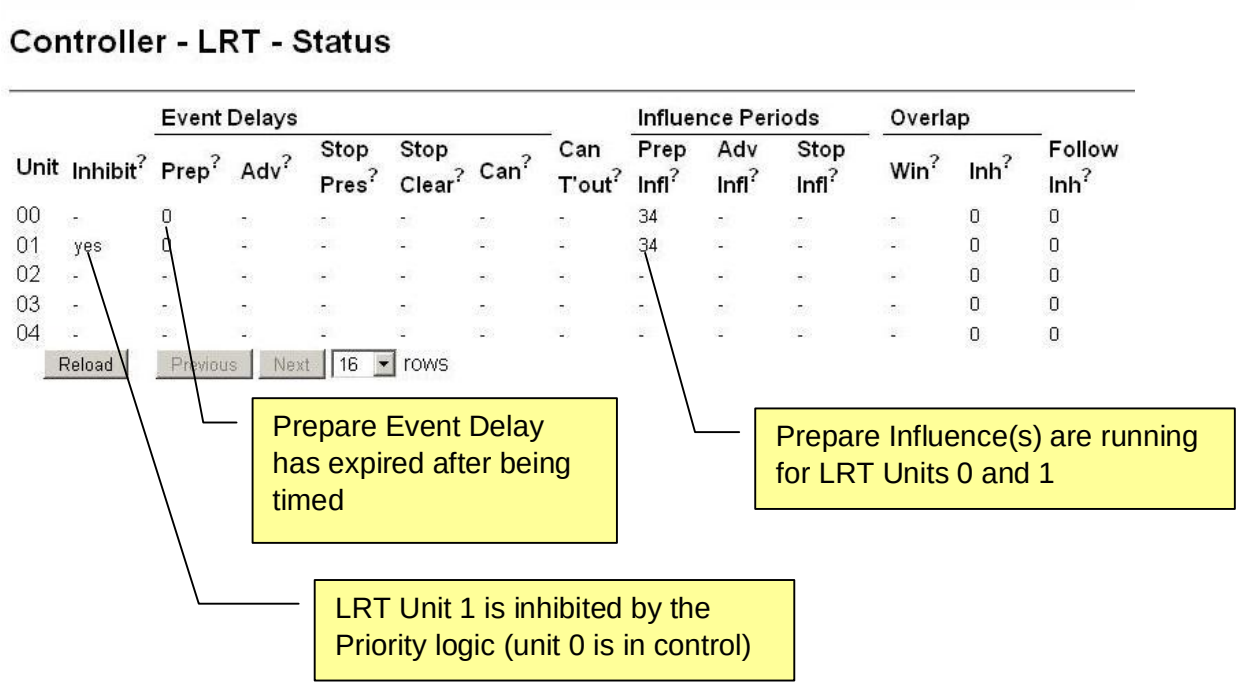


Figure 2-15 - LRT Status - Prepare Influences running

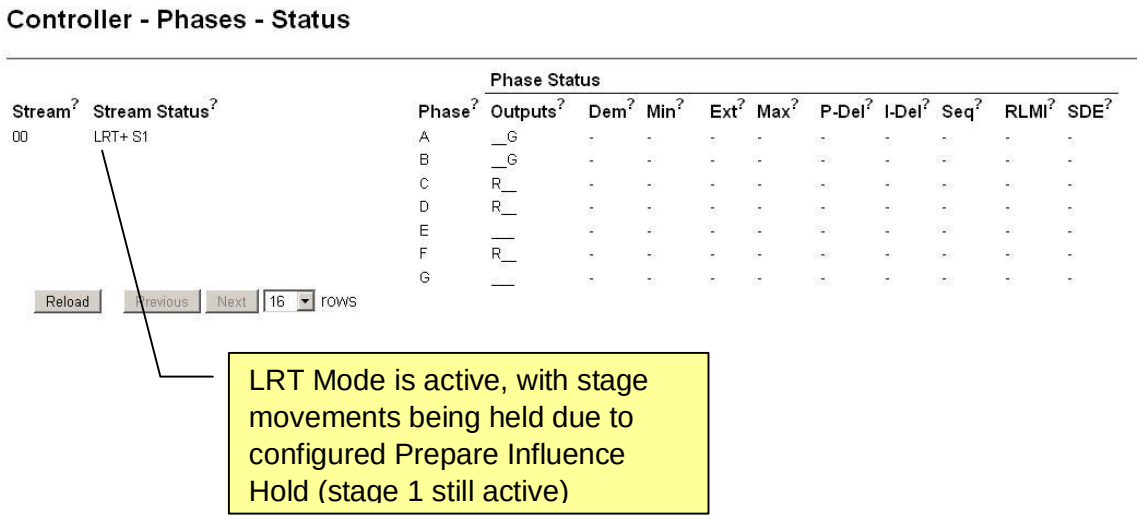


Figure 2-16 - Phase Status - Prepare Influences running

Corresponding Handset commands:

LUS 0:P---,3NA 34

STS 0:LRT+ S1

The Advance Detector typically triggers next. In this example, the Advance Influences start to run after two seconds Advance Event delay for LRT Units 0 and 1.

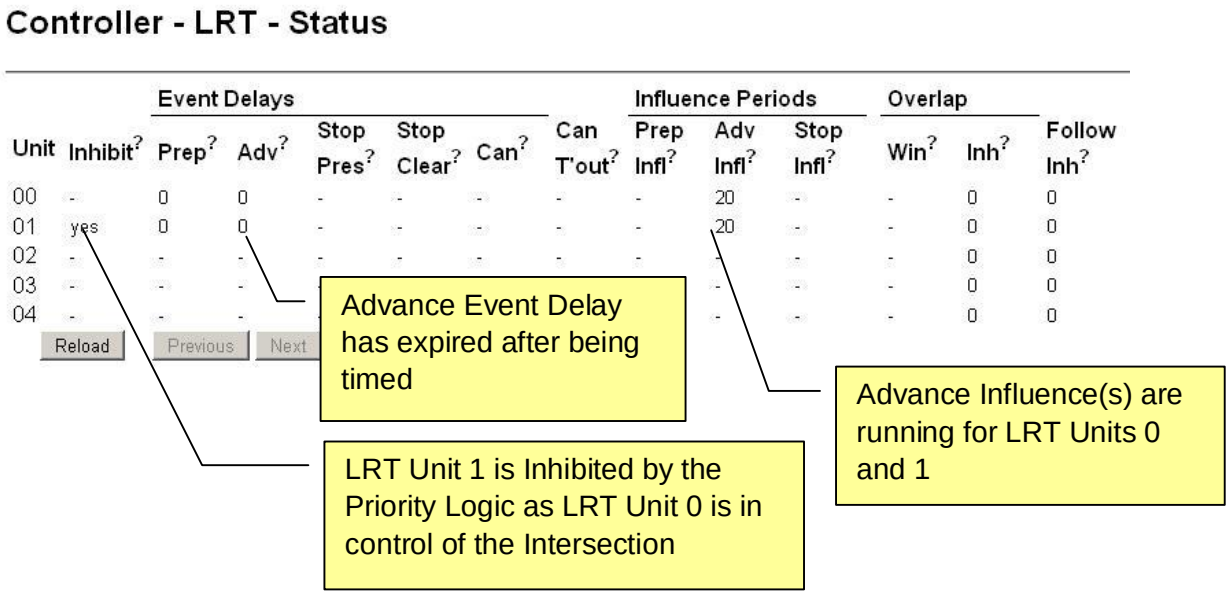


Figure 2-17 - LRT Status - Advance Influences running

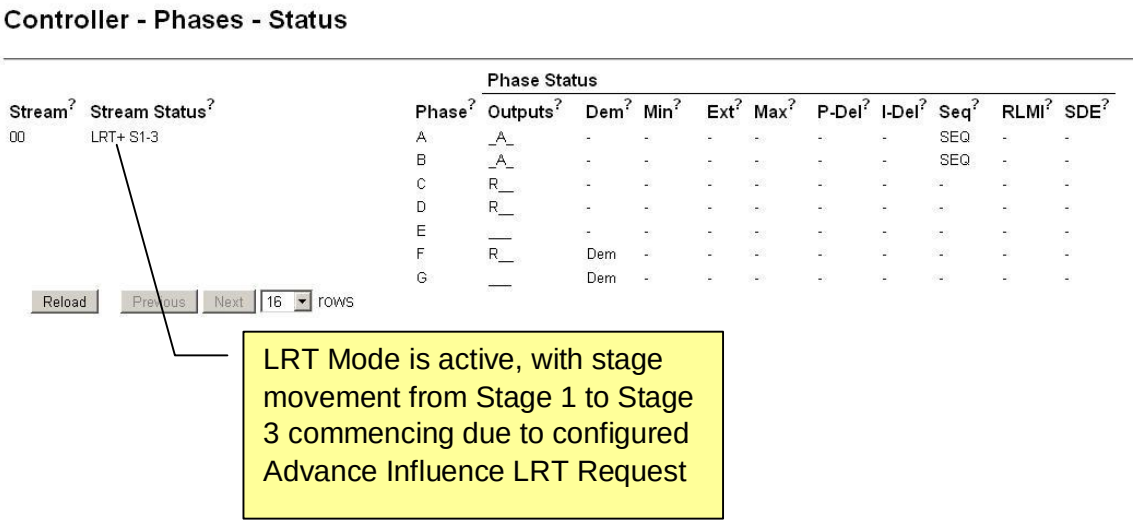


Figure 2-18 - Phase Status - Advance Influences running

Corresponding Handset commands:

LUS 0:PA--,11NA 20

STS 0:LRT+ S1-3

The Advance Influence LRT Request results in the LRT Phase gaining ROW. After an Overlap Window of 34s (during which other LRT Phases in the same stage are allowed to gain ROW), an Overlap Inhibit period is started, during which any units configured to be Overlap Inhibited by LRT Unit 0 will be prevented from controlling the intersection.

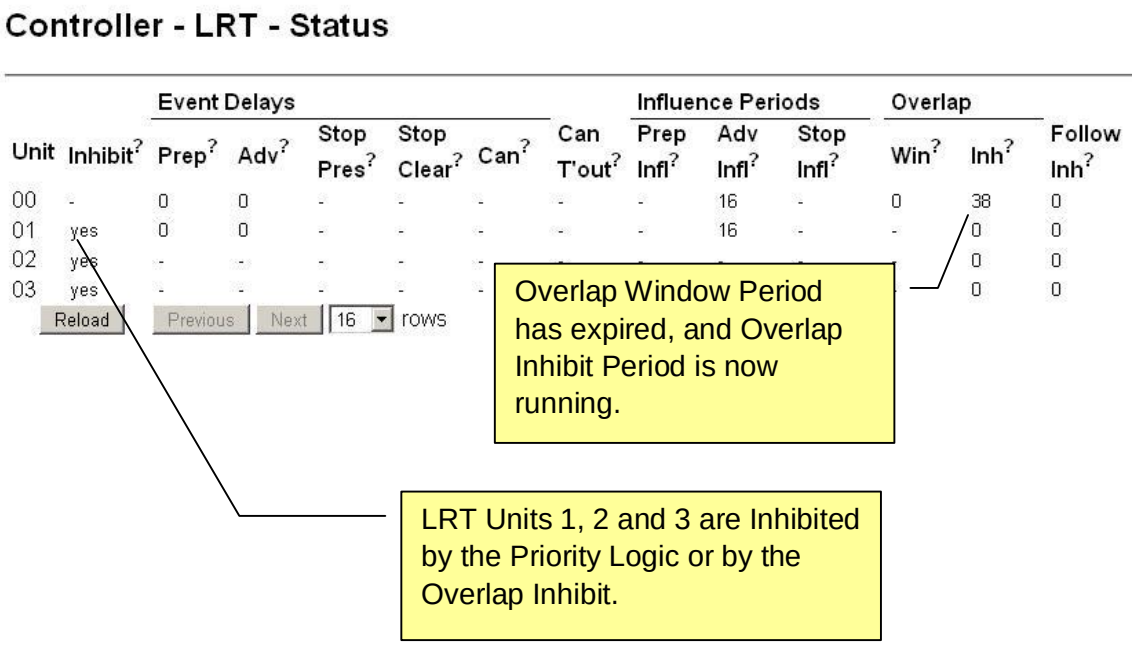


Figure 2-19 - LRT Status - LRT Phase at ROW, Overlap Inhibit running

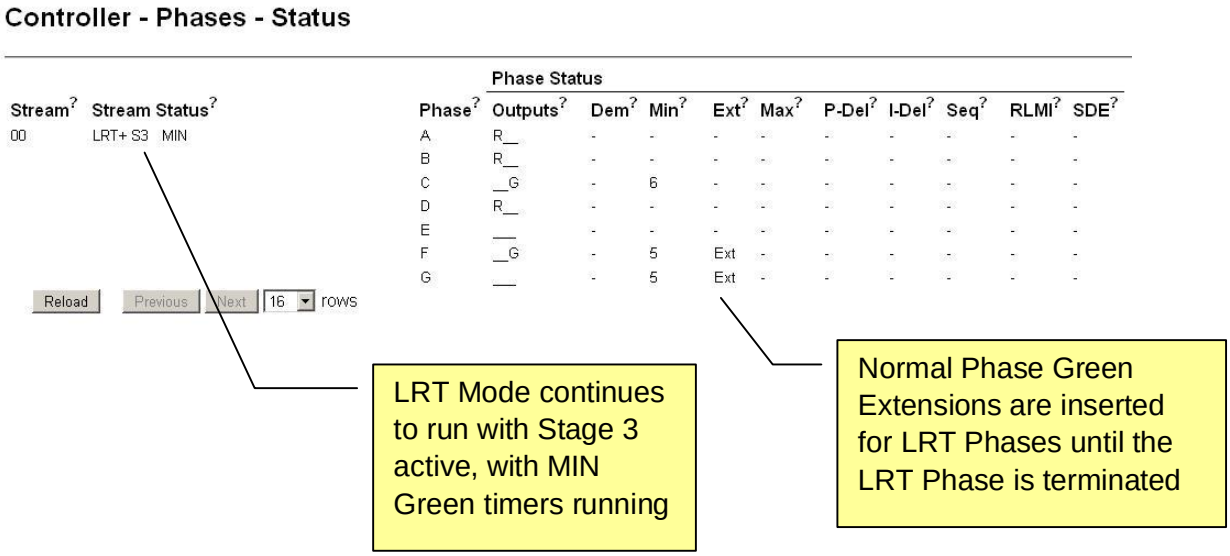


Figure 2-20 - Phase Status - LRT Phase at ROW, Min Green Timers running

Corresponding Handset commands:

LUS 0:PA--,11NA 16,OI 38

STS 0:LRT+ S3 MIN

When the tram reaches the Stopline, an LRT Request and a latched Phase Demand is inserted for the LRT Phase to ensure that the LRT Phase appears at ROW.

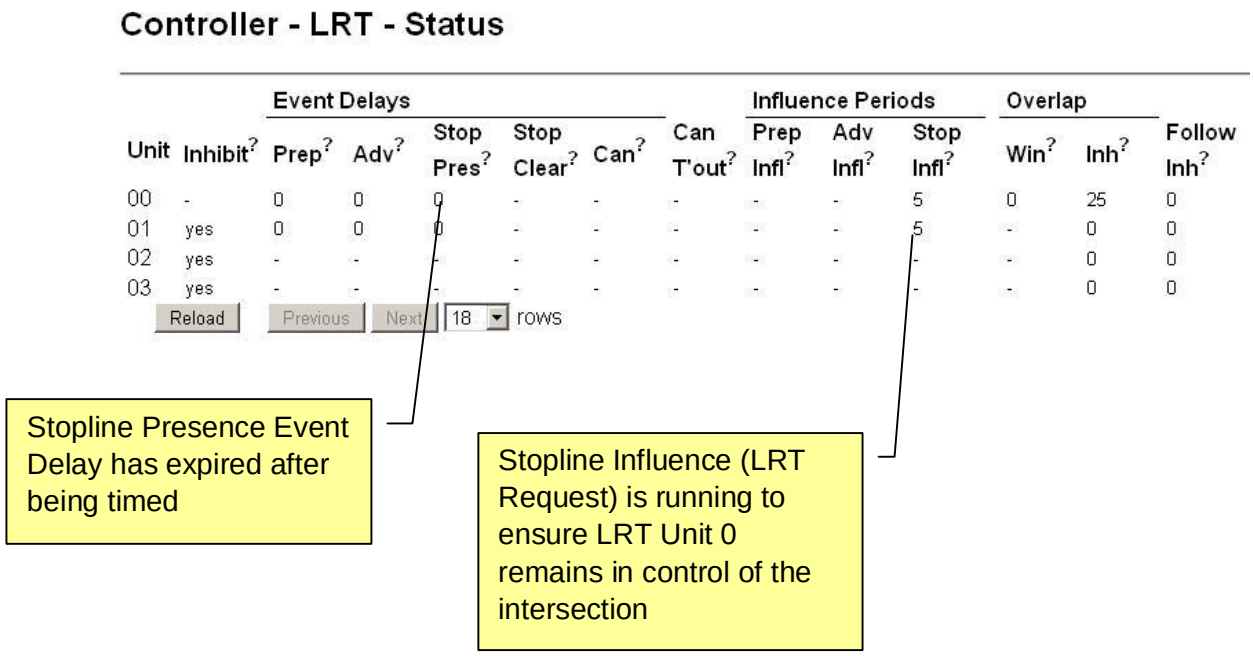


Figure 2-21 - LRT Stopline Influence running

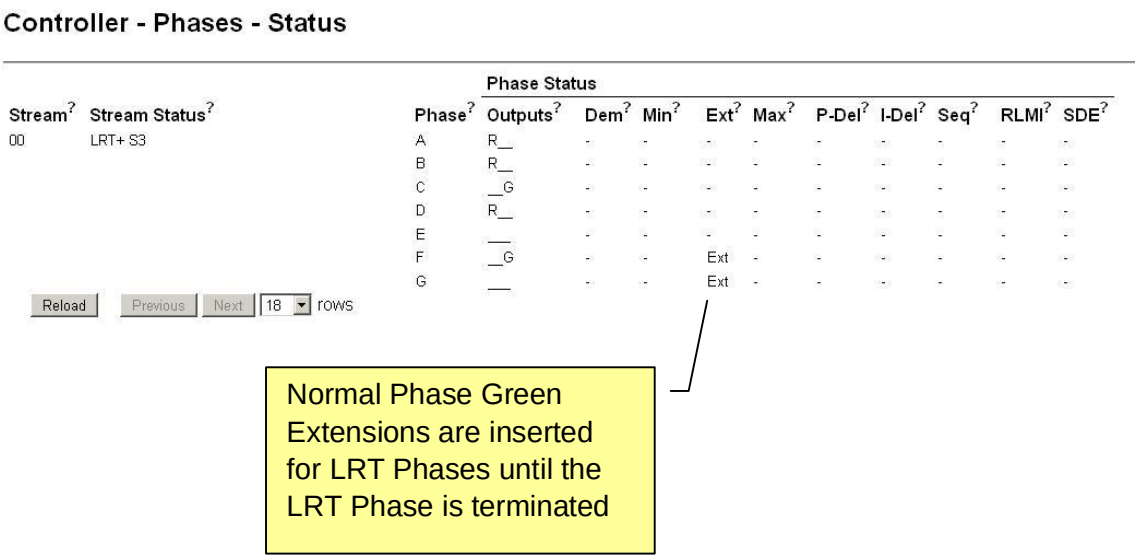


Figure 2-22 - Phase Status - LRT Phase at ROW, Green extensions being inserted

Corresponding Handset commands:

LUS 0:PAS-,SI5,OI 25

STS 0:LRT+ S3

If opposing demands occur while the LRT Phase is at ROW, the Cancel Timeout period runs to limit the duration of the LRT Phase in case the Cancel Event is missed.

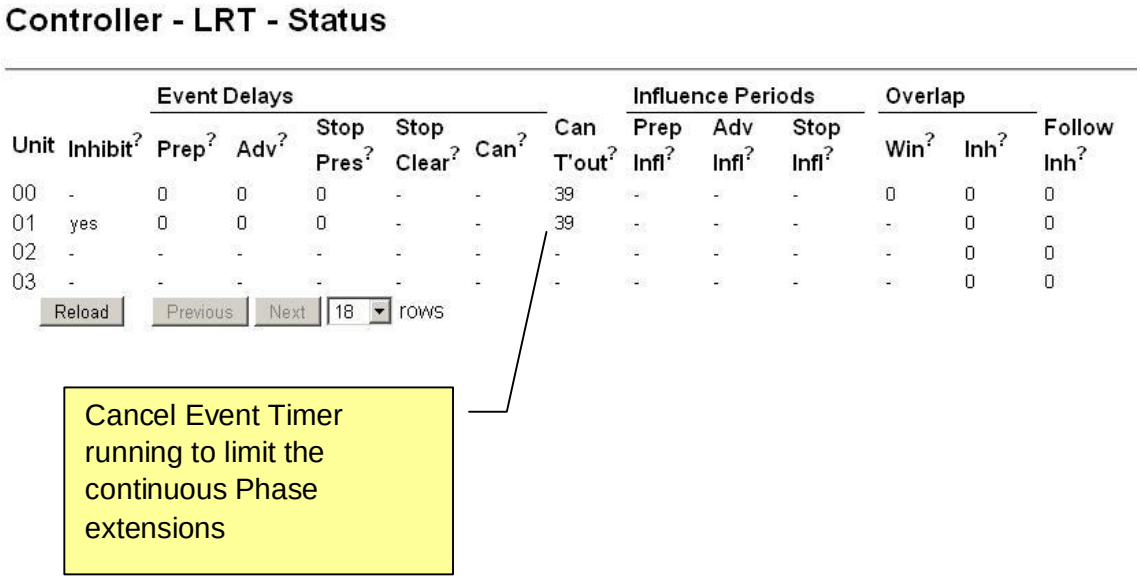


Figure 2-23 - LRT Status - Cancel Timeout period running with Opposing Demands

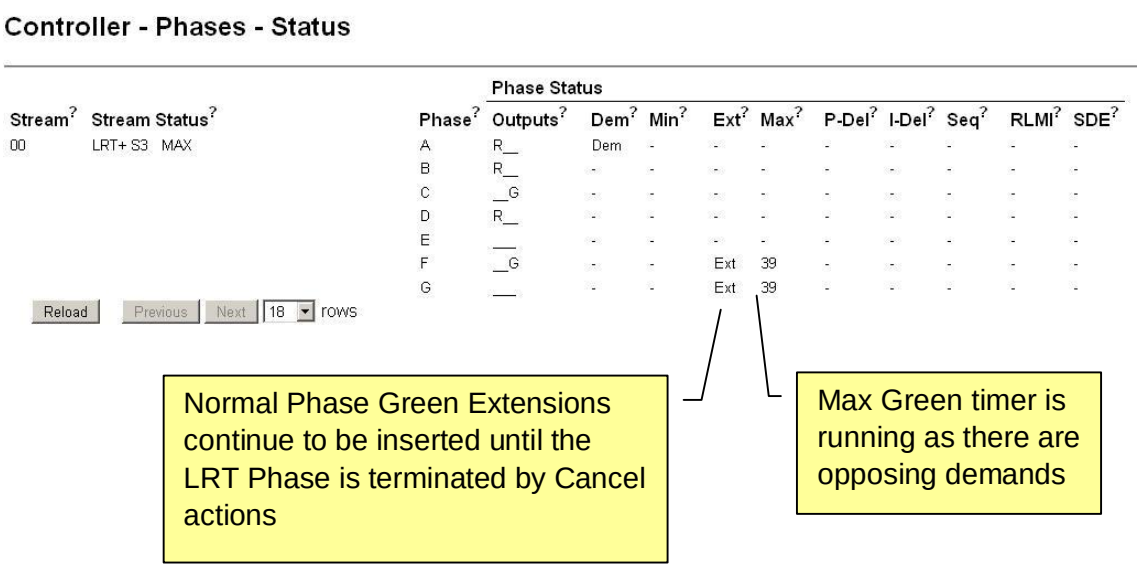


Figure 2-24 - Phase Status - LRT phase extended and Max Timer active

Corresponding Handset commands:

LUS 0:PAS-,CT39,MX39

STS 0:LRT+ S3 MAX

If configured, a Stopline Clearance event will remove the green extensions and terminate the LRT Phase. When the LRT Phase terminates, Intergreen Extensions delay the appearance of conflicting phases until the Cancel actions occur.

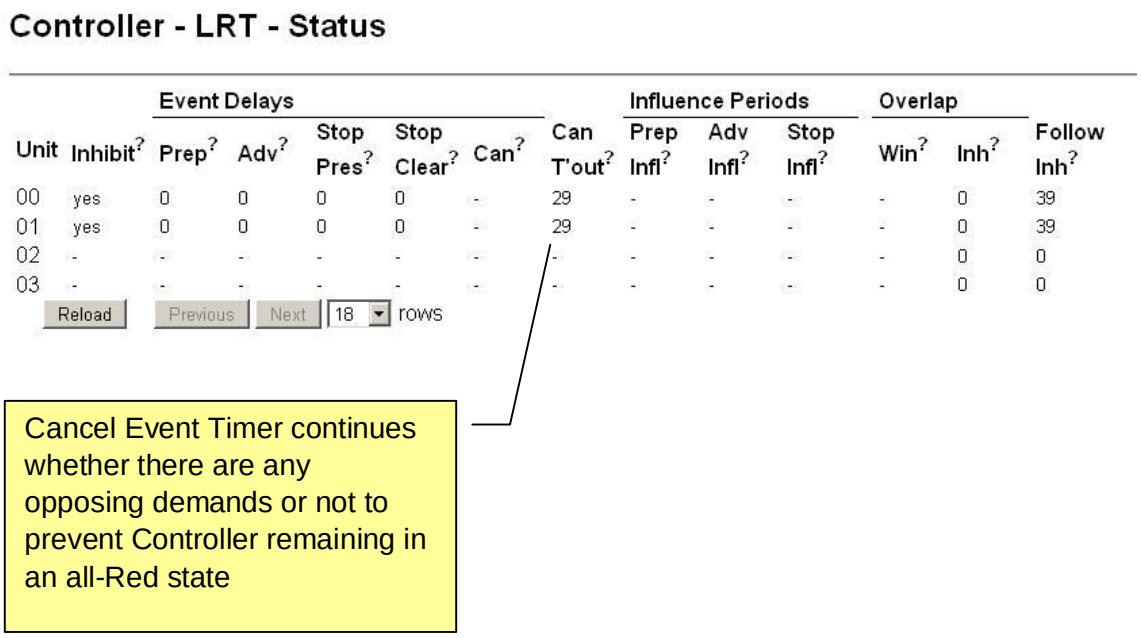


Figure 2-25 - LRT Status - Stopline Clearance

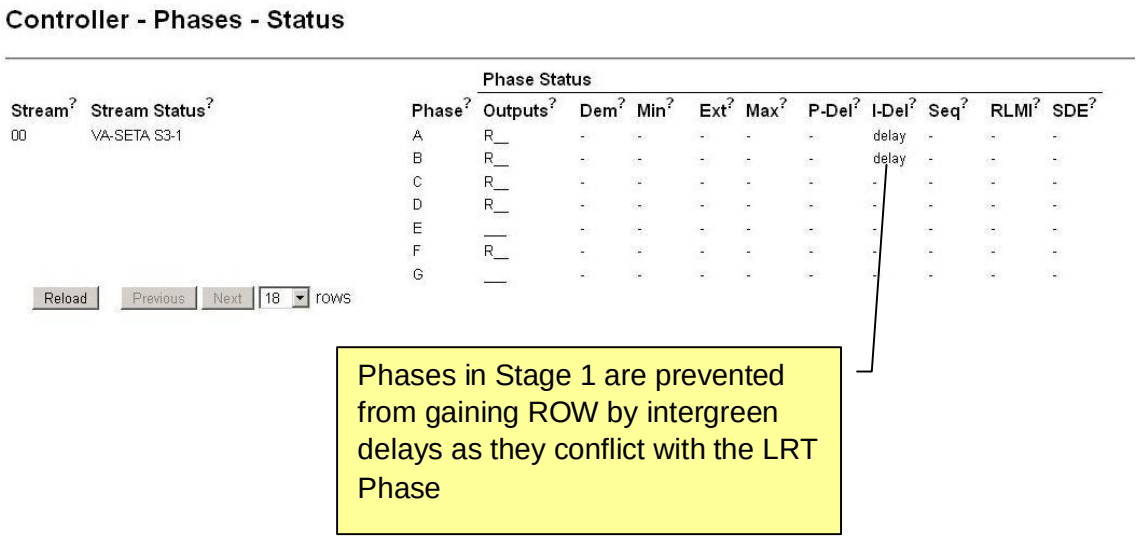


Figure 2-26 - Phase Status - Conflicting Phase appearance delayed by Intergreen Extension

Corresponding Handset commands:

LUS 0:PASC,CT29,FI 39

STS 0:VA-SETA S3-1

When the Cancel actions occur for an LRT Unit (either due to the Cancel Event being triggered and the associated delay expiring, or the Cancel Timeout period expiring), any LRT Influences, Phase and Intergreen Extensions are terminated, and any conflicting phases may now appear at ROW.

Note that Event Delays and Influences for Following Trams are not affected by the Cancel Actions.

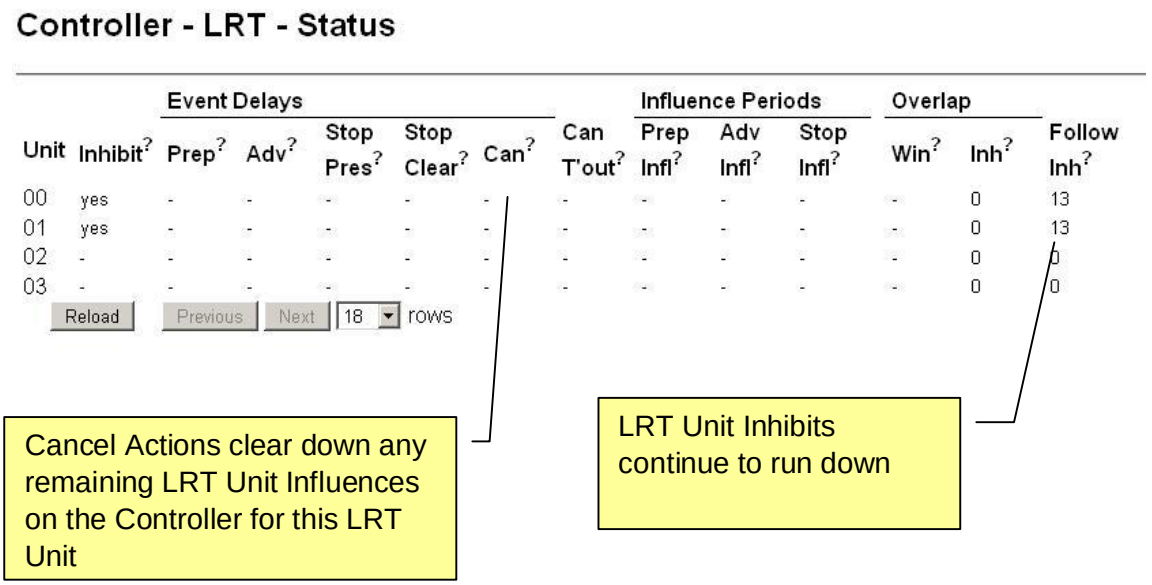


Figure 2-27 - LRT Status - Cancel Actions

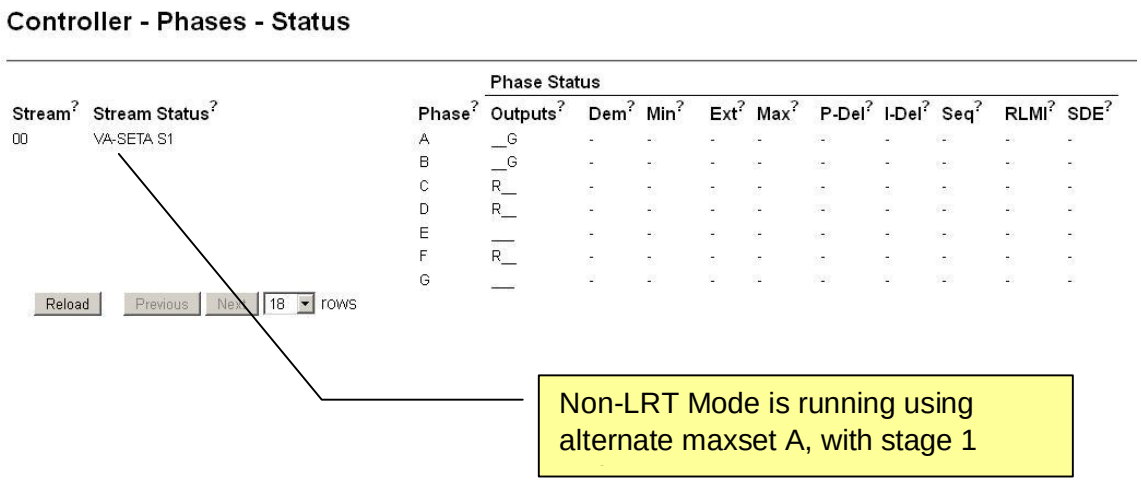


Figure 2-28 - Phase Status - Cancel Actions

Corresponding Handset commands:

LUS 0:----,FI 13

STS 0:VA-SETA S1

Note that if the Cancel Event does not occur and the Cancel Timeout period expires, a revertive LRT Request, phase demand and/or continuous extensions for the LRT Phase can be configured to be inserted once thereafter, thus allowing the LRT Phase to regain ROW as is most expedient for the Controller.